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THESIS

THE DEVELOPMENT AND INITIAL EVALUATION OF THE HUMAN READINESS LEVEL FRAMEWORK

by

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June 2010

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ABSTRACT

Proper measurement and management is necessary to effectively translate capability needs and technology opportunities into stable, affordable, and well-managed acquisition programs. The Technology Readiness Level (TRL) has proven to be the tool and process of choice for assessing the maturity of developing technologies within the Department of Defense (DoD). Yet, the TRL has proven incapable of consistently capturing the human-related aspects of technology development and their association with technology readiness. This thesis describes the initial development and evaluation of the Human Readiness Level (HRL). The purpose of the HRL framework is to complement TRLs in program risk management structures within the Integrated Defense Acquisition, Technology, and Logistics (IDAT&L) Life Cycle Management System. Further development and evaluation of the HRL framework is required beyond what was carried out as part of this thesis. However, the initial framework takes that first step towards providing acquisition professionals a comprehensive guide that ensures human-centric priorities are addressed throughout all phases and milestones of Defense Acquisition.

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LIST OF ACRONYMS AND ABBREVIATIONS

ACAT	Acquisition Category
AoA	Analysis of Alternatives
ASR	Alternative Systems Review
CARD	Cost Analysis Requirements Description
CBA	Capabilities Based Assessment
CDD	Capability Development Document
CDR	Critical Design Review
CDRA	Critical Design Review Assessment
COTS	Commercial off The Shelf
CPD	Capability Production Document
DoD	Department of Defense
DODAF	Department of Defense Architectural Framework
DT	Developmental Testing
ECP	Engineering Change Proposal
EOA	Early Operational Assessment
FAA	Functional Area Analysis
FOC	Full Operational Capability
FOT&E	Follow-on Operational Test and Evaluation
FRP&D	Full-Rate Production and Deployment
FRP DR	Full-Rate Production Decision Review
FNA	Functional Needs Analysis
FSA	Functional Solution Analysis
GOTS	Government off The Shelf
HCI	Human-Computer Interface
HFE	Human Factors Engineering
HHA	Health Hazard Analysis
HMI	Human-Machine Interface
HRL	Human Readiness Level
HSI	Human Systems Integration
HSIA	HSI Assessment

HSIP	HSI Plan
HSIWG	HSI Working Group
HV	Human View
ICD	Initial Capabilities Document
ICW	Interactive Course Ware
ILE	Interactive Learning Environment
ILT	Instructor Led Training
IOC	Initial Operational Capability
IOT&E	Initial Operational Test and Evaluation
IPT	Integrated Product Team
ISD	Integrated System Design
ISP	Information Support Plan
ISR	In-Service Review
ITR	Initial Technical Review
JCIDS	Joint Capabilities Integration and Development System
JQR	Job Qualifications Requirements
JTA	Job Task Analysis
KPP	Key Performance Parameter
KSA	Knowledge Skills and Abilities
LCMP	Life Cycle Management Plan
LRIP	Low-Rate Initial Production
MAIS	Major Automated Information System
MDD	Materiel Development Decision
ME	Manpower Estimate
MER	Manpower Estimate Report
MOS	Military Occupational Specialty
OPEVAL	Operational Evaluation
OV	Operational View
PDR	Preliminary Design Review
PESHE	Programmatic Environmental Safety and Health Evaluation
PHA	Preliminary Hazard Analysis
PHL	Preliminary Hazard List

PM	Program Manager
PQS	Personnel Qualification Standards
PRR	Production Readiness Review
RFP	Request for Proposal
RM	Requirements Manager
SCMPD	System Capability and Manufacturing Process Demonstration
SEP	System Engineering Plan
SFR	System Functional Review
SME	Subject Matter Expert
SOH	Safety and Occupational Health
SOW	Statement of Work
SRD	System Requirements Document
SPS	System Performance Specification
SRR	System Requirements Review
SVR	System Verification Review
TAD	Target Audience Description
TDRA	Top Down Requirements Analysis
TDS	Technology Development Strategy
T&E	Test and Evaluation
TEMP	Test and Evaluation Master Plan
TES	Test and Evaluation Strategy
TRR	Technology Readiness Review
TTE	Technical Training Environment
VCD	Verification of Correction of Deficiencies
V&V	Verification and Validation

EXECUTIVE SUMMARY

This thesis describes the development of an initial Human Readiness Level (HRL) framework, designed to complement the existing Technology Readiness Level (TRL) currently being used within the Integrated Defense Acquisition, Technology, and Logistics (IDAT&L) Life Cycle Management System. Technology maturity assessment tools, such as the TRL, serve as systematic measurement systems that are used as entry and exit criteria for transitioning milestones and are integral components to program risk management structures. Yet, the TRL has proven incapable of consistently capturing the human-related aspects of technology development and their association with technology readiness.

The proposed HRL framework was developed with the aim of adding clarity to technical readiness assessments by emphasizing the socio-technical attributes of system development. Specifically, the HRL aims to reduce technology risks related to the human element by ensuring the adequate incorporation of Human Systems Integration (HSI) during technology maturity evaluations and by explicitly linking technology development to the effective design and specification of human-centered systems in Defense Acquisition. The HRL accomplishes this by providing a time and milestone-sensitive roadmap of activities that: a) detail critical organizational milestones (that ensure functional commitment to HSI); and b) define HSI domain-specific data collection and analysis, and a clear process for their management. The primary measure of HSI risk and maturity level is based on the execution and outcome of those milestone-sensitive management and analytical activities that have been designated in each progressive HRL.

To evaluate the utility of the initial HRLs, two research efforts were carried out. In the first, an evaluation questionnaire was designed to gain feedback as to the overall worth and potential usefulness of the HRL framework. The questionnaire was given to 43 subject matter experts (SMEs) in the fields of HSI and Defense Acquisition. A total of 15 responses were obtained. Results of this evaluation indicated agreement among SMEs that the first iteration of the HRL concept, once fully developed, will serve as a valuable

HSI planning tool and complementary (HSI-specific) metric in program risk management structures. In order to improve the framework, many SMEs recommended expanding the HRL's list of activities to account for a more diverse variety of programs that exist in acquisition.

The second research effort was a case study regarding the usefulness of the HRL framework as applied to a specific acquisition program. Specifically, the HRL was evaluated in its ability to effectively contribute to the creation and sustainment of the acquisition program's HSI Plan (HSIP) for the Ground Control Station Modernization (GMOD). Results of this SME evaluation suggested a general agreement that the HRL framework could serve as a beneficial tool in the development of an acquisition program's comprehensive HSIP. Consistent with the findings from the first research effort, the SME did not feel the HRL framework contained all of the necessary HSI activities to account for all program needs. The feedback and lessons learned from both studies were documented and will serve to form a basis of advocacy for future HRL development efforts.

Further development and evaluation of the HRL concept is required. However, the initial framework presented in this thesis takes that first step towards providing acquisition professionals a comprehensive guide that ensures human-centric priorities are addressed throughout all phases and milestones of Defense Acquisition.

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I. INTRODUCTION

A. PURPOSE

This thesis develops and documents an executable process description of the Human Readiness Level (HRL) to complement the existing Technology Readiness Level (TRL) measurement process currently being used within the Integrated Defense Acquisition, Technology, and Logistics (IDAT&L) Life Cycle Management System. Technology maturity measurement tools, such as the TRL, serve as systematic measurement systems that describe the maturity of a particular technology and allow consistent comparison of maturity to be made between different types of technologies (Saucer, Verma, Ramirez-Marquez, & Gove, 2006). Throughout Department of Defense (DoD) acquisition programs, TRLs are used as entry and exit criteria for transitioning milestones and are integral components to program risk management structures. The proposed HRL measurement framework will add clarity to technical readiness assessments by emphasizing the socio-technical attributes of systems. The HRL aims to reduce technology risks related to the human element by ensuring the inclusion of Human Systems Integration (HSI) considerations during technology maturity evaluations. By capturing human-related components of evolving technologies, the acquisition and Science & Technology (S&T) communities will decrease operational and development risks linked to insufficient HSI.

B. OVERVIEW

The DoD relies heavily on the technological superiority of its weapon systems and armed forces to protect U.S. interests. Although the United States has produced some of the finest modern weapon systems in the world, the Government Accountability Office (GAO) points out that its acquisition programs often incur cost overruns, schedule delays, and performance shortfalls that weaken DoD's buying power (GAO, 2006). This ongoing challenge is due in part to DoD's difficulty in managing technology maturity. In numerous reports to Congressional Committees, the GAO has addressed the problems

with proceeding in system development with immature technologies and has detailed how best practices offer improvements to the way the DoD incorporates new technology into weapon system programs. According to a 2001 GAO report, *"organizations that use best practices recognize that delaying the resolution of technology problems until product development—analogous to the Engineering and Manufacturing Development phase—can result in at least a ten-fold cost increase; delaying the resolution until after the start of production could increase costs by a hundred-fold"* (GAO JSF, 2001, p. 1–2). The GAO went on to illustrate this point by providing the following comparison between the Joint Direct Attack Munition (JDAM) and the Comanche helicopter programs.

> *For example, the Joint Direct Attack Munition used modified variants of proven components for guidance and global positioning. It also used mature, existing components from other proven manufacturing processes for its own system for controlling tail fin movements. The munition was touted for its performance in Kosovo and was purchased for less than half of its expected unit cost. However, the Comanche helicopter program began with critical technologies such as the engine, rotor, and integrated avionics at Technology Readiness Levels (TRLs) of 5 or below [see later for detailed discussion of TRLs]. That program has seen 101 percent cost growth and 120-percent schedule slippage as a result of these low maturity levels and other factors.* (GAO JSF, 2001, p. 7)

To enhance the ability of programs to select mature technologies for inclusion in their programs, the GAO recommended the use of TRLs (Graettinger et al., 2002). The first published description of technology readiness can be found in a 1989 paper titled, "*The NASA Technology Push towards Future Space Mission Systems*." In that paper, Stanley Sadin and his co-authors presented a seven-level readiness metric that assessed the risk associated with technology development. In the years that followed, the metric evolved into the nine levels that exist today. The TRL describes the maturity of technology elements with levels that begin in the earliest stages of scientific investigation (Level 1) to the successful use in the system (Level 9). Organizations, such as the Air Force Research Laboratory (AFRL) promotes TRLs as a means of evaluating the readiness of technologies to be incorporated into a weapon or other type of military system (Graettinger et al., 2002).

Despite the practical utility of using TRLs to measure technology readiness, they fail to account for the critical human element. By inadequately considering the human capacity or requirements as part of the system, the ability to enhance human/system performance, maximize operational effectiveness, and reduce life cycle cost (LCC) is compromised (711 HPW/HPO, 2009). Therefore, additional methodologies are needed to ensure that human-centric priorities are implemented throughout all phases and milestones of defense acquisition. To this end, it is the goal of this thesis to provide the acquisition and S&T communities a human-centric approach to assessing technology maturity in order to avoid operational and development risks associated with insufficient consideration of the human element.

C. NEED FOR HUMAN SYSTEMS INTEGRATION

The level of technology that the U.S. provides to its armed forces is simply unparalleled. However, even with sophisticated technologies, optimized total systems performance still depends on the warfighter’s ability to use the technology fully and effectively (AFHSIO, 2009). HSI serves as the critical link that infuses human roles, structures, processes, and constraints into the design of systems to achieve total systems performance. By integrating HSI strategies throughout a system’s life cycle, programs are better able to identify, track and resolve human-related issues and ensure a balanced development of both human and technological capabilities (MoD HFI DTC, 2008). This is accomplished by incorporating functional areas, referred to as domains. These domains are identified in the DoD instruction on the operation of the Defense Acquisition System (DoDI 5000.02) and are illustrated in Table 1:

Table 1. HSI Domains and Definitions (After 711 HPW/HPO, 2009)

HSI Domain	***Definition***
Manpower	The number and mix of personnel (military, civilian, and contractor) authorized and available to train, operate, maintain, and support each system acquisition.
Personnel	The human aptitudes, skills, knowledge, experience levels, and abilities required to operate, maintain, and support the system at the time it is fielded and throughout its life cycle.
Training	The instruction and resources required to provide personnel with requisite knowledge, skills, and abilities to properly operate, maintain, and support the system.
Human Factors Engineering	The comprehensive integration of human capabilities and limitations (cognitive, physical, sensory, and team dynamic) into system design, development, modification and evaluation to optimize human-machine performance for both operation and maintenance of a system. Human factors engineering designs systems that require minimal manpower, provide effective training, can be operated and maintained by users; and are suitable and survivable.
Environment	The factors concerning water, air, and land and the interrelationships which exist among and between water, air, and land and all living things.
Safety	The design and operational characteristics that minimize the possibilities for accidents or mishaps to operators which threaten the survival of the system.
Occupational Health	The design features that minimize risk of injury, acute and/or chronic illness, or disability, and/or reduced job performance of personnel who operate, maintain, or support the system.
Survivability	The characteristics of a system that reduce risk of fratricide, detection, and the probability of being attacked; and that enable the crew to withstand man-made or natural hostile environments without aborting the mission or suffering acute and/or chronic illness, disability, or death.

Habitability	Factors of living and working conditions that is necessary to sustain the morale, safety, health, and comfort of the user population which contribute directly to personnel effectiveness and mission accomplishment, and often preclude recruitment and retention problems.

Although HSI is a fundamental component of a total systems approach, the successful integration of HSI into systems engineering and acquisition life cycles continues to be a challenge. The Air Force 711th Human Performance Wing points to the following barriers that often exist in program development:

- Lack of alignment of processes between the traditional practice of HSI and the human-based technical domains;
- Lack of alignment between human technical areas and the systems engineering and program management practices of DoD acquisition; and
- Inability to communicate, which causes an inability to share data or information throughout the acquisition phases and beyond (711 HPW/HPO, 2008).

Therefore, recognizing this need for HSI involvement and a sustainable human approach to system acquisition, there has been an international emergence of what is being termed, the Human View. The Human View was originally created to be used as a complementary element to the Operational, System and Technical Standards Views of the Ministry of Defence Architectural Framework (MODAF). The Human View aims to clarify the role of Human Factors Integration (HFI; the United Kingdom (UK) equivalent of HSI) when creating Enterprise Architectures in support of acquisition (MoD HFI DTC, 2008).

Architectures such as MODAF or the US-created DoD Architectural Framework (DoDAF) produce common systems engineering (SE) approaches to development, presentation, and integration of current and future systems. Within DoD, architectures are created for a number of reasons. From a practical perspective, experience has shown that the management of large organizations employing sophisticated systems in pursuit of

joint missions demands an organized, repeatable method for evaluating investments and investment alternatives, as well as the ability to effectively implement organizational change, create new systems, and deploy new technologies (DoD, 2007). Towards this end, the Human View connects HSI to DoDAF by supporting system design and development that effectively and affordably integrates human capabilities and limitations.

Although the Human View has been tailored to the major characteristics of architectural models, HSI practitioners working within Defense Acquisition have observed the potential for extended applications. An example of this extended application, which serves as the focus of this thesis, was conceived by Dr. Hector Acosta of the Air Force 711th Human Performance Wing (a co-advisor of this thesis). After recognizing the potential for using Human View technical details and attributes to structure HSI initiatives within technology readiness determinations, Dr. Acosta created the concept of the HRL. This thesis will build upon the work of Dr. Acosta by developing the HRL concept to form a defined and executable process description. This will allow HRLs to immediately become applicable to the acquisition and S&T communities. HRLs will facilitate the unification and integration of HSI processes within technology evaluations, to include formal and informal technology maturity assessments. Ultimately, HRLs will provide DoD acquisition programs the ability to reduce technology risks related to the human element and will help to maximize both return on investment (ROI) and system performance.

D. SCOPE

This thesis focused on defining Human Readiness Levels for use in technology development life cycles, using the detailed elements of the Human View. The tasks comprising this thesis included the following:

- Conduct in-depth analysis of current DoD technology development processes and maturity standards (i.e., Technology Readiness Assessment (TRA), TRL, etc.) adhered to in the Defense Acquisition System and document shortfalls in the consideration of human aspects of systems.

- Synthesize the technical details of the Human View and its relation to DoDAF and explicitly develop its linkage to the concept of an HRL.
- Analyze the Human View/HRL amalgamation's validity and usability in acquisition and S&T environments and begin the effort towards elaborating the HRL concept throughout the lifecycle of a system.

E. THESIS ORGANIZATION

A brief literature review of the significance and history of technology maturity is discussed in Chapter II. This review encompasses the nine Technology Readiness Levels used by government and industry to measure technology maturity and program risk, and highlights the inability of the readiness levels to adequately capture human-specific elements of evolving technologies. To approach the issue, this thesis develops and defines the complimentary concept of the Human Readiness Level. Because the HRL employs the technical details of the Human View to structure HSI initiatives specifically within technology maturity assessments, the history and utilization of the Human View also is discussed in Chapter II. The subsequent chapters are devoted to introducing and analyzing the HRL's value, validity, and usability in acquisition and S&T environments. Chapter III details the development process behind the HRL and presents the first iteration of the HRL concept. Chapter IV discusses the initial evaluation of the HRL concept. This included Subject Matter Expert (SME) feedback that focused on accuracy, ease of use, and completeness of the HRL framework. Chapter V describes the succeeding validation of the HRL model being practically applied in a brief case study. Chapter VI summarizes this thesis effort and discusses future implications for HRL use in Defense Acquisition.

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II. LITERATURE REVIEW

A. TECHNOLOGY

1. Technology Defined

The National Aeronautics and Space Administration (NASA) Technology Plan defines technology as the practical application of knowledge to create the capability to do something entirely new or in an entirely new way. This can be contrasted to scientific research, which encompasses the discovery of new knowledge from which new technology is derived, and engineering that uses technology derived from this knowledge to solve specific technical problems (Bilbro, 2007). Similarly, Dictionary.Com defines technology as follows:

> *The branch of knowledge that deals with the creation and use of technical means and their interrelation with life, society, and the environment, drawing upon such subjects as industrial arts, engineering, applied science, and pure science; a technological process, invention, method, or the like; the sum of the ways in which social groups provide themselves with the material objects of their civilization.* (Technology, n.d.)

Science and technology are terms that are often seen as one and the same. However, William Nolte (2008) points out in his book, *"Did I Ever Tell You about the Whale? Or Measuring Technology Maturity,"* that science and technology are related, but not identical. He states that science is the search for new knowledge for knowledge's sake, while technology takes that knowledge of science and makes it do something useful for society. Therefore, when scientific knowledge is put to use, we have technology. The form in which technology takes shape can be seen in hardware (i.e., cell phone, computer, aircraft, etc.) or in non-material technologies (i.e., software, new practices or procedures; Nolte, 2008). This understanding of what technology is and what it may encompass will serve as the contextual foundation for the remaining discussions in this chapter's literature review.

The concept of technology maturity and how it is currently measured in government and industry will first be examined below, followed by the limitations inherent in such measurements. After which, the discussion focuses on the need for a human approach to technology readiness and describes the resulting technological immaturity that occurs when the human is not adequately incorporated. This chapter ends with the emergence of the Human View and details the ability of the Human View to integrate and shape human-specific elements into the design and implementation of technology.

2. Technology Maturity

With an understanding of what technology is and what it may encompass, it is appropriate to now examine what technology maturity might mean and how it is currently measured. In Dr. Tom Cruse's 2006 report, '*Multi-Dimensional Assessment of Technology Maturity*' he points out that the term, *maturity* implies aging, or growth. With technology growth, Cruse states that the technology itself does not necessarily change, but rather our understanding of the technology changes. He explains that as our understanding improves or grows, the technology's usefulness should improve as well. Therefore, the more we learn about a technology, the better we can apply it to meet our needs. For the most part, the customer or end user of a technology intuitively knows what it means for a technology to mature because they will often wait for a new, immature product to "get the bugs out" before purchasing. The expectation for a technology to become more mature, more capable of meeting needs and requirements after it "grows up" is the basic premise of technological maturity (Nolte, 2008).

Within the DoD, the evolution and management of technology maturity continues to be a subject of study and emphasis. In their work on best business practices in the last two decades, the GAO studied a number of leading commercial firms to determine key factors in successful product development. They reported that one such key factor is maturing a new technology far enough to get it into the right size, weight, and configuration needed for the intended product. After this is demonstrated, the technology is said to be at an acceptable level for product development (Graettinger et al., 2002).

According to the GAO, "… *no element is more important than having technology advanced enough to meet requirements, but also mature enough to be predictably managed and available at the start of the product development cycle."* They further stated that, *"maturing new technology before it is included on a product is perhaps the most important determinant of the success of the eventual product—or weapon system"* (GAO, 1999, p. 12).

To subjectively quantify the maturity of certain technologies and to ensure that new technologies are vigorously pursued and successfully moved into program development, the adoption of a disciplined and knowledge-based method is often recommended (GAO, 1999). The beginnings of such a method can be traced back as early as 1969, where NASA articulated the status of new technology planned for use in future space systems. The examples used were between the then-established practice of the "flight readiness review," and a new idea through which the level of maturity of new technologies could be assessed—the "technology readiness review."

Although NASA used the emerging concept of technology readiness for some time after, the actual readiness level scale was not devised and published until 1989. That year, in an effort to develop a "systems-technology model," Mr. Stan Sadin of the Office of Aeronautics and Space Technology codified seven levels of technology readiness. The seven readiness levels showed how the more traditional breakdown of research and development were incorporated into four loosely defined categories (Nolte, 2008): basic research; feasibility; development; and demonstration

These readiness levels marked a significant change in emphasis on the part of NASA where technology had previously been viewed as merely having a supporting role. This change in role for technology was the result of a revision in the National Space Policy stating that NASA's technology program "… *shares the mantle of responsibility for shaping the Agency's future..."* The new emphasis on technology's responsibility was cause for a reassessment of how technologies were developed and infused, with a goal of approaching technology development and infusion in a much more systematic way to increase the likelihood of success (JB International, n.d.). As Sadin, Povinelli, and Rosen (1989) point out, when historical records are analyzed, it can be demonstrated that the

difference between success and failure is traceable to the adequacy, or depth, of the advanced research and technology program pursuing technology readiness.

Within DoD, the concept of technology readiness was not entirely embraced until 1999. That year, the GAO conducted an assessment of how best practices offer improvements to the way DoD incorporates new technologies into Defense Acquisition programs. The GAO concluded that *"the experiences of DoD, and the commercial technology development cases GAO reviewed, indicate that demonstrating a high level of maturity before new technologies are incorporated into product development programs puts those programs in a better position to succeed"* (GAO, 1999, p. 3). Soon after, in a 2001 memorandum, the Deputy Undersecretary of Defense for Science and Technology officially endorsed the use of the Technology Readiness Level (TRL) as the standard format for measuring technology maturity in new major programs within Defense Acquisition (Graettinger et al., 2002).

TRLs follow a scale from 1 (*basic research*) to 9 (*system operation*). A technology determined to be at TRL 1 is at the lowest level of technology readiness, where "scientific research begins to be translated into applied research and development" (GAO, 2006, p. 56). By the time the technology has reached a TRL 9, the technology has progressed through formulation of an initial concept for application, proof of concept, demonstration in a laboratory environment and realistic environment, and integration into a system, and has been "system qualified" and then "system proven." This last state of development, where the technology is operating under actual mission conditions, is TRL 9 (Valerdi, 2004). Table 2 provides the DoD's original technology readiness levels and descriptions from a systems perspective with supplemental definitions provided in Table 3 (separate matrices for DoD's hardware and software TRLs are detailed extensively in Appendices A and B).

Table 2. DoD Technology Readiness Levels (After GAO, 2006)

Technology Readiness Level	***Description***
1. Basic principles observed and reported.	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples might include paper studies of a technology's basic properties.
2. Technology concept and/or application formulated.	Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative and there may be no proof or detailed analysis to support the assumption. Examples are still limited to analytic studies.
3. Analytical and experimental critical function and/or characteristic proof of concept.	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
4. Component and/or breadboard. Validation in laboratory environment.	Basic technological components are integrated to establish that they will work together. This is relatively "low fidelity" compared to the eventual system. Examples include integration of "ad hoc" hardware in a laboratory.
5. Component and/or breadboard validation in a relevant environment.	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so it can be tested in a simulated environment. Examples include "high fidelity" laboratory integration of components.
6. System/subsystem model or prototype demonstration in a relevant environment.	Representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high-fidelity laboratory environment or in simulated operational environment.

7. System prototype demonstration in an operational environment.	Prototype near, or at, planned operational system. Represents a major step up from TRL 6, requiring demonstration of an actual system prototype in an operational environment such as in an aircraft, vehicle, or space. Examples include testing the prototype in a test bed aircraft.
8. Actual system completed and qualified through test and demonstration.	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.
9. Actual system proven through successful mission operations.	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. Examples include using the system under operational mission conditions.

Table 3. Additional Definitions of TRL Descriptive Terms (From DoD, 2009)

Term	***Definition***
Breadboard	Integrated components that provide a representation of a system/subsystem and that can be used to determine concept feasibility and to develop technical data. Typically configured for laboratory use to demonstrate the technical principles of immediate interest. May resemble final system/subsystem in function only.
High Fidelity	Addresses form, fit, and function. A high-fidelity laboratory environment would involve testing with equipment that can simulate and validate all system specifications within a laboratory setting.
Low Fidelity	A representative of the component or system that has limited ability to provide anything but first-order information about the end product. Low-fidelity assessments are used to provide trend analysis.

Model	A functional form of a system, generally reduced in scale, near or at operational specification. Models will be sufficiently hardened to allow demonstration of the technical and operational capabilities required of the final system.
Operational Environment	Environment that addresses all the operational requirements and specifications required of the final system to include platform/packaging.
Prototype	A physical or virtual model used to evaluate the technical or manufacturing feasibility or military utility of a particular technology or process, concept, end item, or system.
Relevant Environment	Testing environment that simulates both the most important and most stressing aspects of the operational environment.
Simulated Operational Environment	Either (1) a real environment that can simulate all the operational requirements and specifications required of the final system or (2) a simulated environment that allows for testing of a virtual prototype. Used in either case to determine whether a developmental system meets the operational requirements and specifications of the final system.

To illustrate how technologies progress from initial concept to proven performance within the readiness levels, the following hypothetical example about an airborne communications radio is provided:

> *First, the idea for a new radio is conceived. The idea reaches TRL 3 when analytical studies and some tests of the technology's elements, such as a circuit, back it up. When initial hand-built versions of all of the radio's basic elements are connected and tested together, the radio reaches TRL 5. This is sometimes referred to as a "breadboard" article; although it may function like a radio, it does not look like one because the individual parts are attached to plywood and hand-wired together. When the technology is built into a generic model, which is well beyond the breadboard tested in TRL 5, and demonstrated in a laboratory environment, the radio reaches TRL 6. This model represents the last level of demonstration before the radio becomes tailored for application to a specific aircraft. When the components are assembled inside a case that*

> *resembles the final radio design and are demonstrated aboard a surrogate for the intended aircraft, the radio reaches TRL 7. TRL 8 is reached when the radio is put in its final form, installed in the intended aircraft's cockpit, and tested in conjunction with the other aircraft equipment with which it must interface. TRL 9 is achieved when the radio is successfully operated on the aircraft through several test missions.* (GAO, 1999, p. 22–23)

The TRL offers many benefits to the S&T and acquisition communities. For example, they provide a snapshot of a technology's maturity at a given instant and can be used to establish benchmarks for maturity goals. The TRL can also serve as a communication device in those cases where a technology developer must hand off a technology to another organization for product or system development. TRLs can assist both sides in understanding exactly what each is required to do. By providing a common reference point for the technology developer and user, TRLs assist in eliminating misunderstandings and ambiguities in the technology transition process (Nolte, 2008).

B. LIMITATIONS OF THE TRL

Despite the practical utility of using TRLs to measure technology readiness, they do, however, have significant limitations. For instance, author Jim Smith (2005) states that TRL definitions often combine several different aspects of technology readiness into one metric, thus "blurring" the different contributors to readiness. An example of this can be seen in how the U.S. Army Communications Electronics Command (CECOM) defines a TRL 7 in their draft software TRL scale (Graettinger et al., 2002):

> *Represents a major step up from TRL 6, requiring demonstration of an actual system prototype in an operational environment… Algorithms run on the processor of the operational system and are integrated with actual external entities. Software support structure is in place. Software releases are in distinct versions. Frequency and severity of software deficiency reports do not significantly degrade functionality or performance.*

This description combines the functionality of algorithms, the maintainability of a software support structure, and the reliability of software deficiency reports to indicate a specific level of readiness at TRL 7. The problem, however is that the manner in which

these factors are combined makes it difficult to understand how any one aspect influences the overall readiness of the technology (Smith, 2005).

Similarly, William Nolte states:

> *The TRL scale measures maturity along a single axis, the axis of technology capability demonstration. A full measure of technology maturity, or in the commercial world, product maturity, would be a multi-dimensional metric. It's not uncommon to find references to 12 or more dimensions of product or technology maturity. One writer speaks of 16 different dimensions of maturity. The TRL measures only one of the 16.* (Hobson, 2006, p. 2)

In an attempt to provide a more complete measure of technology maturity within the Defense Acquisition Management System, the GAO (2006) recommended that DoD expand its use of Technology Transition Agreements (TTAs) and metrics to cover aspects of technology maturity not explicitly attended to by the TRL (Appendix C summarizes the management of technology maturity in the Defense Acquisition Management System). Within this recommendation, the GAO specifically emphasized the utilization of other maturity metrics, such as the Manufacturing Readiness Level (MRL) to support better management of technology risk and to avoid the pitfalls of proceeding with immature technologies (GAO, 2006; Appendix D details the impact of immature technologies). Although they were only recently introduced, MRLs have already gained wide acceptance throughout government and industry (AFRL/RXM, 2009).

In recent years, many readiness levels like the MRL have surfaced. Other examples of readiness levels developed in varying degrees include the Design Readiness Level, Integration Readiness Level, and System Readiness Level. Ultimately, the efforts towards creating alternative readiness levels have been to replace, amplify, or compliment existing TRL definitions to better measure and manage specific programmatic areas of concern (Sauser, Ramirez-Marquez, Magnaye, & Tan, 2008).

C. A HUMAN-CENTERED APPROACH IS NEEDED

While there continues to be an increasing number of TRL variants being created, there has not, however, been any specific effort towards capturing the socio-technical

attributes of technology and its association with technology readiness. Without a human-centered focus, the Human Factors Integration (HFI) Defence Technology Centre (DTC) within the Ministry of Defence (MoD) states that programs are ill-prepared to identify, track, and resolve human-related issues that would ensure the balanced development of both human and technological capabilities (MoD HFI DTC, 2008).

Historically, the lack of appropriate Human Systems Integration (HSI; the U.S., Canadian, and Australian equivalent to HFI) has been a significant stumbling block for many programs, even those with supposedly mature technologies. Whether it is redesigns, substandard system performance, or dangerous system failures endangering life and equipment, poor HSI involvement in technology maturation can be catastrophic (Technology Development (TD) 1-12 Implementation Team, 2008). Two unfortunate, yet classic examples of this can be seen in Table 4:

Table 4. Three Mile Island Incident/Loss of the Mars Climate Orbiter (After Technology Development (TD) 1-12 Implementation Team, 2008)

Three Mile Island Incident
On March 28, 1979, operators at Three Mile Island, a nuclear power plant in Pennsylvania, made a series of mistakes that led to a near meltdown of the plant's reactor core. This accident was caused by a cascade of equipment failures and operator errors. The result of the accident was a release of approximately 1200 millirem/hour of radiation into the environment, forcing the evacuation of several thousand residents of the surrounding area. Fortunately, there were no deaths as a direct result of the incident. The near meltdown of the reactor occurred when an emergency relief valve at the top of the pressurizer failed to close, resulting in a loss of the pressurizer steam bubble and a loss of reactor control system pressure and quantity. The indicator lights on which the operators were relying to determine the position of the relief valve led them to believe that the valve was closed. However, the indicator light was not displaying the actual system state—rather; it was showing the presence of a signal commanding the valve to close. In other words, the operators believed the relief valve was closed when in reality the valve was open, though it had been commanded to close. This led the system operators to conclude falsely that a leak had occurred, and they began to act accordingly.

The operators continued to make errors that increased the volatility of the system, such as confusing reactor B with reactor A (a problem directly attributable to the control panel layout). Not until two hours into the accident, when an operator who had recently arrived finally realized that the relief valve was at fault and performed the proper actions to correct the problem. In the end, the investigation by the Nuclear Regulatory Commission into the human factors (HF) aspects of the accident determined that the human errors which occurred during the incident were not due to operator deficiencies but rather to inadequacies in equipment design, information presentation, emergency procedures, and training.

Loss of the Mars Climate Orbiter (MCO)

The Mars Climate Orbiter (MCO) Mission objective was to orbit Mars as the first ever interplanetary weather satellite and provide a communications relay for the Mars Polar Lander (MPL). The MCO was launched on December 11, 1998, and was lost sometime following the spacecraft's Mars Orbit Insertion (MOI) maneuver. The spacecraft's carrier signal was last seen at 09:04:52 UTC on Thursday, September 23, 1999.

During the 9 month journey from Earth to Mars, propulsion maneuvers were periodically performed to remove angular momentum buildup in the on-board reaction wheels (flywheels). These Angular Momentum Desaturation (AMD) events occurred 10-14 times more often than was expected by the operations navigation team. This was because the MCO solar array was asymmetrical relative to the spacecraft body as compared to Mars Global Surveyor (MGS) which had symmetrical solar arrays. This asymmetric effect significantly increased the Sun-induced (solar pressure-induced) momentum build-up on the spacecraft. Additionally, the angular momentum (impulse) data was in English, rather than metric, units. This measurement confusion resulted in small errors being introduced in the trajectory estimate over the course of the 9 month journey. At the time of Mars insertion, the spacecraft trajectory was approximately 170 kilometers lower than planned. As a result, MCO either was destroyed in the atmosphere or re-entered heliocentric space after leaving Mars' atmosphere. The Board recognized that mistakes occur on spacecraft projects. However, sufficient processes are usually in

place to catch these errors before they become critical to mission success. Unfortunately for MCO, the root cause was not caught by the processes in-place in the MCO project.

The MCO Mishap Investigation board (MIB) determined that the root cause of the loss of the MCO spacecraft was the failure to use metric units in the coding of a ground software file, "Small Forces", used in trajectory models. Specifically, thruster performance data in English units instead of metric units was used in the software application code titled SM_FORCES (small forces). The AMD file contained the output data from the SM_FORCES software. The data in the AMD file was required to be in metric units per existing software interface documentation, and the trajectory modelers assumed the data was provided in metric units per the requirements. Inadequate employee and programmer training were cited as the reasons for the omission of the English-to-metric conversion factor in the software program used to generate the AMD files.

The two examples described above highlight how human errors can result in disastrous events, particularly when they are synergistically compounded. Therefore, to reduce errors, maximize performance, and enhance safety, proper human-centered design must be accomplished. This effort must attend to all areas that impact the human in the system, including training, source selection, human-computer interaction, ergonomics, safety, survivability, habitability, quality of life, and human performance in extreme environments (e.g., space, underwater, and Polar expeditions; O'Connor & Cohn, 2010).

The Air Force 711th Human Performance Wing states clearly that if humans, as part of an integrated human-technology system, are not considered in the design and implementation, the system may not achieve the desired operational capability (711 HPW/HPO, 2009). Expanding on this belief, the UK Vice Admiral Sir Jeremy Blackham stated:

> *Capability is not just a function of equipment performance, but depends on a combination of interacting elements. Some of the most difficult issues to address lie in the human factors area. The types of systems we are specifying and procuring now will shape the roles, responsibilities and career paths of future servicemen and women. They will also have to be operated in very demanding circumstances of fatigue, hunger, stress and*

even fear, by the sort of men and women we recruit. They will therefore determine not just the working environment of our people, but ultimately their utility in these harsh conditions will determine our operational success and our ability to retain the right people. (MoD, 2007, p. 4)

Marine Corps General James Mattis, head of Joint Forces Command made a similar point while addressing a joint war-fighting conference. Calling on industry to focus on human-centered design, General Mattis was quoted saying, *"… if what you're doing is going to enable the human interface, then you're on the right track… if not, you don't want things that take geniuses on the battlefield to operate. We need to create systems and organizations and equipment that don't need a master's degree in math"* (Cavas, 2010, para. 8).

With today's increasingly interconnected, diverse, and distributed work environments, the focus of human-centered design and technology development is more important now than ever. Current DoD acquisition policy requires optimizing total system performance and minimizing the cost of ownership through a "total system approach" to acquisition management (DoDD 5000.01, 2003). As seen in the Three Mile Island incident, as well as the loss of the Mars Climate Orbiter, the total system includes not only the prime mission equipment, but also the people who operate, maintain, and support the system; the training and training devices; and the operational and support infrastructure (DAU, 2009). The DoDI 5000.02, which details the operation of the Defense Acquisition System states:

The program manager (PM) shall have a plan for HSI in place early in the acquisition process to optimize total system performance, minimize total ownership costs, and ensure that the system is built to accommodate the characteristics of the user population that will operate, maintain, and support the system. (DoDI 5000.02, 2008, p. 60)

In addition, Chapter 6 of the Defense Acquisition Guidebook (DAG) states:

The HSI domains (manpower, personnel, training, environment, safety and occupational health, human factors engineering, survivability, and habitability) can and should be used to help determine and work the science and technology gaps to address all aspects of the system (hardware, software, and human). The program manager should integrate system requirements for the HSI domains with each other, and also with

> *the total system. As work is done to satisfy these requirements, It is vitally important that each HSI domain anticipate and respond to changes made by other domains or which may be made within other processes or imposed by other program constraints.* (DAU, 2009, section 6.2, para. 1).

Even with such guidance, incorporating HSI into technology and system life cycles early continues to be a challenge. The policies that are currently set forth unfortunately address HSI as an act rather than a process. DoDI 5000.02, for example, thoroughly defines and details the five phases of the Defense Acquisition Life Cycle (see Figure 4 in Appendix C); however, it does not fully integrate or define HSI's role within each of those phases. In addition, there is no solid guidance on the preferred sequencing of needed HSI activities, nor are there any HSI-specific task requirements to support adequate accountability and implementation. Without an appropriate HSI process in place, the consistent management and mitigation of human-related risk inherent with all developing technologies and systems will continue to be a challenge.

D. EMERGENCE OF THE HUMAN VIEW

Recognizing the abovementioned need for HSI involvement and a sustainable human approach to system acquisition, there has been an international emergence of what is being termed, the Human View. The Human View is a supplementary view to existing Architectural Frameworks, such as the DoD Architectural Framework (DoDAF) that explicitly models the human elements being shaped in the process of capability design. By doing so, HSI is considered early and related closely to the design and implementation of technology (MoD HFI DTC, 2008). The ultimate purpose of the Human View is to enable effective HSI processes within the design of complex, large-scale, socio-technical systems.

Architecture, as defined by DoD, is the structure of components, their relationships, and the principles and guidelines governing their design and evolution over time (DoDAF V1.5, 2007). Architecture frameworks, such as DoDAF are used within engineering and acquisition communities to produce common approaches to development, presentation, and integration of current and future systems. The DoDAF provides the guidance and rules for developing, representing, and understanding

architectures based on a common denominator across DoD, Joint, and multinational boundaries. It provides insight for external stakeholders into how the DoD develops architectures. The DoDAF is intended to ensure that architecture descriptions can be compared and related across programs and mission areas, while establishing the foundation for analyses that supports decision-making processes throughout the DoD (DoDAF V1.5, 2007).

Within DoD, architectures are created for a number of reasons. From a practical perspective, the management of large organizations employing sophisticated systems, technologies, and services in pursuit of complex, joint missions demands a structured, repeatable method for evaluating investments and investment alternatives. Architectures help to implement organizational change effectively, create new systems, deploy new technologies, and offer services which add value to decisions and management practices (DoDAF V2.0, 2009). Newer architecture framework versions, such as DoDAF V2.0 address Net-centric, System of Systems, and System/Services concepts while emphasizing data-centric processes to support DoD managers (as process owners and/or decision-makers).

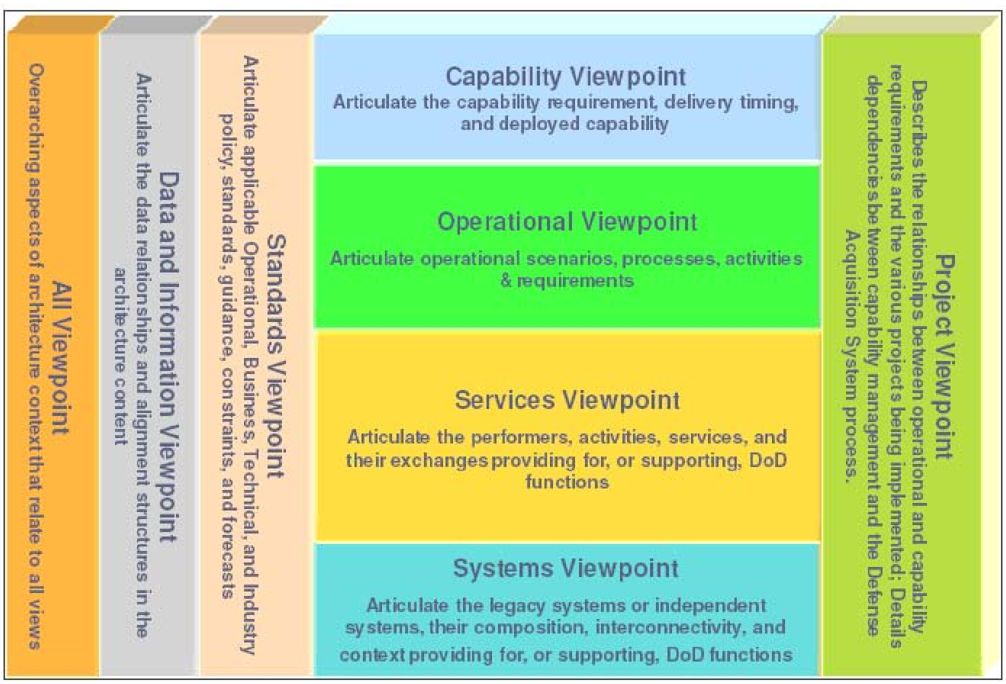

Figure 1. Architecture Viewpoints in DoDAF V2.0 (From DoDAF V2.0 Vol. 1, 2009)

Figure 1 provides a graphical representation of the different perspectives or viewpoints that logically combine to describe system architectures in DoDAF V2.0. It is important to note that a view is only a presentation of a portion of the total architectural data, in the sense that a photograph provides only one view of the object within the picture, not the entire representation of that object. The viewpoints are organized into eight basic sets with each set depicting certain architecture attributes as described in Table 5:

Table 5. DoDAF V2.0 Viewpoint Attributes (After DoDAF V2.0 Vol. 1, 2009)

Viewpoint	***Architecture Attributes***
All Viewpoint	Provides overarching descriptions of the entire architecture and defines the scope and context of the architecture
Capability Viewpoint	Captures the goals associated with the overall vision for executing a specified course of action, or the ability to achieve a desired effect under specific standards and conditions through combinations of means and ways to perform a set of tasks
Data and Information Viewpoint	Captures business information requirements and structural business process rules, and it describes the information that is associated with information exchanges
Operational Viewpoint	Captures the organizations, tasks, or activities performed, and information that must be exchanged between them to accomplish DoD missions
Project Viewpoint	Captures how programs are grouped in organizational terms as a coherent portfolio of acquisition programs
Services Viewpoint	Captures system, service, and interconnection functionality providing for, or supporting, operational activities
Standards Viewpoint	The minimal set of rules governing the arrangement, interaction, and interdependence of system parts or elements
Systems Viewpoint	Captures the information on supporting automated systems, interconnectivity, and other systems functionality in support of operating activities

The above viewpoints do not, however, adequately portray the human as a unique part of the system, nor do they capture the human-centered design aspects needed to ensure the effectiveness of human operated systems, such as users' requirements, or capabilities and limitations (Handley & Smillie, 2009). It is due to this deficiency that the Human View was created.

The *North Atlantic Treaty Organization (NATO) Human View Handbook* states that the Human View forms a basis for decisions by stakeholders by providing a structured linkage from the engineering community to the manpower, personnel, training, and human factors engineering communities. It provides a way to integrate HSI into the mainstream acquisition and systems engineering process by promoting early and often consideration of human roles. Additionally, it provides early coordination of task analysis efforts by both system engineering and HSI teams. Table 6 provides an overview of NATO's current set of Human View products (greater detail of all Human View products and their potential elements can be found in Appendix E).

Table 6. NATO Human View Products Overview (After Handley & Smillie, 2009)

Human View	***Description***
HV-A: Concept	A conceptual, high-level representation of the human component of the enterprise architecture framework.
HV-B: Constraints	Sets of characteristics that are used to adjust the expected roles and tasks based on the capabilities and limitations of the human in the system.
HV-C: Tasks	Descriptions of the human-specific activities in the system.
HV-D: Roles	Descriptions of the roles that have been defined for the humans interacting with the system.
HV-E: Human Network	The human to human communication patterns that occur as a result of ad hoc or deliberate team formation, especially teams distributed across space and time.
HV-F: Training	A detailed accounting of how training requirements, strategy, and implementation will impact the human.

HV-G: Metrics	A repository for human-related values, priorities and performance criteria, and maps human factors metrics to any other Human View elements.
HV-H: Human Dynamics	Dynamic aspects of human system components defined in other views.

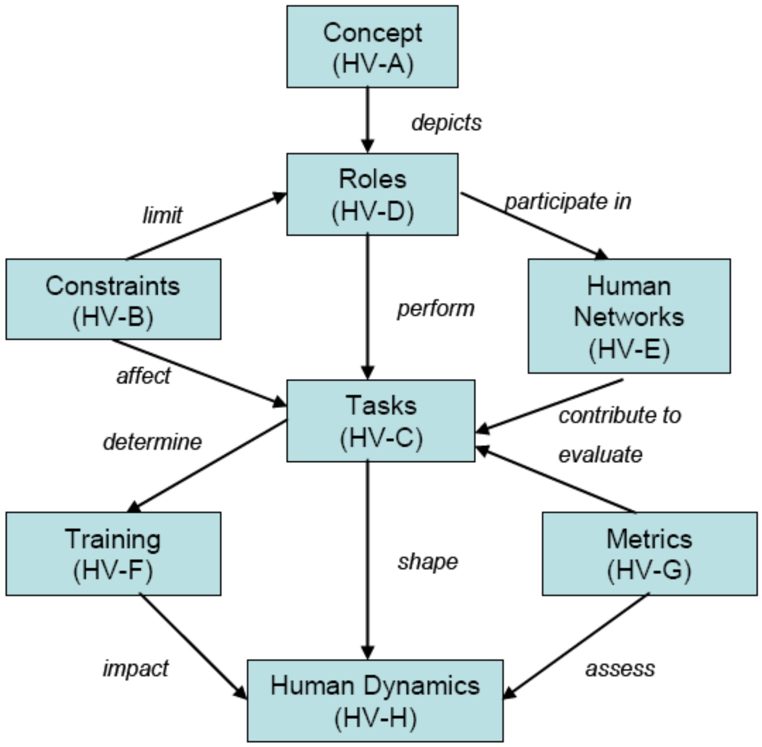

Figure 2. NATO Human View Product Relationships (After Handley & Smillie, 2009)

The NATO Human View and its set of products facilitate design decisions by identifying relevant elements or specific sets of data. Relationships can be defined between the products that express dependencies between the data. Figure 2 depicts some of the relationships that have been established between the Human View products (Handley & Smillie, 2009).

The approach NATO has taken with their Human View framework has emphasized the explicit need of merging seamlessly and efficiently with good systems engineering practice. It establishes a logical and systematic framework for specifying the

professional data collection and analysis actions needed for HSI implementation and it makes explicit human, crew, and team socio-behavioral processes as integral to total system performance.

An example of the Human View products being used to capture human elements can be seen in a case study based on a subset of the U.S. Army's Future Combat System (FCS). The FCS program was a modernization initiative designed to link soldiers to a wide range of weapons, sensors, and information systems by means of a mobile ad hoc network architecture that enables joint interoperability, shared situational awareness, and the ability to execute highly synchronized mission operations. It consists of the network, the soldier, and 14 systems, including eight manned ground vehicles, two classes of unmanned aerial systems, two classes of unmanned ground systems, unattended ground sensors, and the Non-Line of Sight Launch System (Handley & Smillie, 2009). Table 7 indicates the type and scope of information captured in each of the Human View products for the FCS example.

Table 7. Content of Human View Products for FCS Example (From Handley & Smillie, 2009)

Human View Products	FCS Case Study Products Description
HV-A Concept	A graphic that shows a soldier connected through a network to 14 systems. This represents the FCS "One Soldier, One Network, 14 Systems" concept.
HV-B Personnel Constraints: Manpower Projections (HV-B1)	A matrix that shows the distribution of the 50 personnel in an Infantry Platoon by both the 12 identified roles and across the five platoon vehicles.
HV-B Human Factor Constraints: Health Hazards (HV-B5)	A table that shows the operating limits of infantry personnel to noise and heat, as well as rest requirements.
HV-C Tasks	A table that decomposes the platoon level tasks of Tactical Road March and Reaction to Ambush to 15 squad level tasks.
HV-D Roles	A table listing the 12 roles defined for the Infantry Platoon and their required Military Occupational Specialty (MOS). An additional table indicates the assignment of the roles to the previously defined tasks. A third table indicates the controllers and system interfaces available to each role.
HV-E Human Network	A matrix that indicates the different team compositions within the platoon, both by vehicle and by functionality; the type of interactions i.e., collaboration, coordination, and supervision, are also indicated. For example, within three of the vehicles are two rifle squads lead by a team leader, with supervision from a squad leader. Across the vehicles are the drivers who coordinate maneuvers.
HV-F Training	A table that indicates the current training level for each MOS type indicated in the role table, and the additional training required to attain the knowledge, skill, and abilities to operate the FCS systems.
HV-G Metrics	A listing of the platoon level performance metrics for conducting Counter Ambush Operations, as well as individual squad level performance standards based on FCS specifications.

The subset of the FCS that was analyzed included the capabilities and limitations of an infantry platoon and the resources available in the Infantry Carrier Vehicle (one of the 14 FCS systems). The case study focused on the tasks involved during a tactical road march and the platoon's reaction to an enemy ambush. As illustrated above, the Human View products were able to capture the different roles the platoon members assumed during these operations (i.e., platoon leader, driver, etc.), the interactions between the platoon functional teams, and the FCS technology interfaces. Ultimately, a fully populated and developed Human View would reflect the product of iterative analyses

describing details of human sensory, perceptual, emotional, social, cognitive, ergonomic, biomechanical, motor, communicative, and decisional processes consistent with man-equipment interactions.

E. SUMMARY

In order to effectively translate capability needs and technology opportunities into stable, affordable, and well-managed acquisition programs, proper measurement and management of technology maturity must occur. The TRL has proven to be the tool of choice for describing the maturity of developing technologies. Yet, due to fundamental limitations, the TRL has been incapable of capturing the human-related attributes of technology and its association with technology readiness.

The need for a better fusion of human-centric elements is not, however, unique to only technology maturity management. This issue continues to surface in all phases of the acquisition life cycle and it is in that very reason the international community created the Human View. The Human View, which is a complimentary view to existing architectural frameworks, establishes a logical and systematic structure for specifying the professional data collection and analysis actions needed for HSI implementation.

The next chapter introduces the first iteration of the proposed Human Readiness Level and its attempt towards applying the technical details of the Human View and other existing sources to structure HSI initiatives specifically within technology maturity assessments. The steps taken in developing the HRL concept will first be discussed, followed by the initial validation studies in subsequent chapters.

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III. HUMAN READINESS LEVEL DEVELOPMENT

A. OVERVIEW

In Defense Acquisition risk management structures, developing technologies are monitored and managed for associated risk by way of Technology Readiness Assessments (TRAs) and their assignment of TRLs (see Appendix C for more details regarding the TRA process). The lower the level of technology readiness, the more ground must be covered to bring the technology to the point at which it can meet the intended product's cost, schedule, and performance requirements with little risk. As mentioned in Chapter II, the TRL does not adequately capture socio-technical elements of developing technology and without such attention; risk related to the human will continue to exist. This chapter describes the development of the first iteration of the HRL. The method used in creating the HRL, as well as the resulting framework is discussed below.

B. CREATING THE HRL CONCEPT

To establish the critical groundwork for developing the concept of the HRLs, multiple teleconferences and two separate five-day workshops took place at the 711th Human Performance Wing/Human Performance Integration Directorate of the Air Force Research Laboratory. The development team consisted of the thesis author and Dr. Hector Acosta, HSI professional and co-advisor of this thesis.

Step 1: Literature review

The first step was to conduct an extensive literature review and document analysis. The literature reviewed is discussed in the previous chapter. From this review it was decided that the NATO Human View was the most appropriate framework on which to base the HRL. The reason for this was that it: a) provided a structured linkage from the engineering community to the technical domains of HSI; b) it established a logical and systematic framework for specifying the professional data collection and analysis actions

needed for effective HSI implementation; and c) it provided early coordination of task analysis efforts by both system engineering and HSI teams.

Step 2: Establishing the underlying principles

For the HRL framework to be accepted and useful to the HSI and acquisition communities, four underlying principles were used to guide the development of the HRL framework.

1. Any risk management framework that is developed for HSI implementation should be consistent with existing risk management processes and, to the extent possible, complement existing program risk management metrics.

2. HSI should define a process that supports the development and fielding of systems that minimize life cycle costs and result in human-centered designs that complement total system performance. This needs to be done in a way that is consistent with the realities of system engineering risk management and the need for rational, informed developmental tradeoffs.

3. The model should facilitate vigorous HSI implementation early in the acquisition timeline to decrease risk of resulting life cycle cost penalties.

4. In the context of a competitive cost, schedule, and performance-driven acquisition enterprise, any incremental expense to implement HSI must be identified in order to be funded. There currently is no process in DoD that identifies the incremental expenses involved with implementing HSI.

Step 3: Development of HRL level definitions

The decision was made to develop nine HRL levels to be consistent with the existing TRL structure. The reason for this decision was to encourage acceptance and use among the S&T and acquisition communities, particularly in developmental risk management structures. Each of the nine HRLs was given a preliminary definition. The following list provides the HRL definitions and a brief rationale for each:

1. *Activation of Human Systems Integration: base-lining and commitment.* At this level, the priority is to establish HSI infrastructure to support and manage initial planning and analysis efforts.

2. *Human Systems Integration analysis suite in support of component technology development.* The goal of this second level is to ensure that substantial preliminary assessments and documentation has been accomplished.

3. *Component human touch point (i.e., human-system interaction, to include hardware and software) resolution: refining requirements thresholds.* The primary objective of this level is to continue HSI analysis efforts across all domains, while identifying and communicating appropriate technological thresholds.

4. *Component human touch point engineering parameters and human performance indicators.* The fourth level continues with iterative analyses and updates to HSI domain considerations bearing on the developing technology.

5. *Limited system human performance parameters/demonstration.* In this level, HSI activities focus on supporting the increasing fidelity of breadboard technology.

6. *Field (relevant environment) validation of human performance prototypes.* The goal of this sixth level is to make certain significant HSI evaluations are conducted in relevant environments.

7. *Final Developmental Test & Evaluation/human performance parameters.* The objective for this level is to ensure HSI involvement in system T&E.

8. *Operational Test & Evaluation/human performance parameters.* This level focuses on accomplishing specific HSI analyses to support OT&E events.

9. *Sustainment: Initiation of capability gap feedback cycle.* The goal of the ninth and final level is to begin iterative review and verification of fielded systems to support ongoing sustainment.

Step 4: Development of more detailed level descriptions

The definitions developed in the previous stage established the framework to allow for the more detailed development of the HRLs. This was accomplished by

elaborating the products of the Human View and explicitly developing their linkage to the concept of an HRL. There were five sub-steps carried out at this stage of the development process:

1. An exhaustive list of HSI goals and considerations was developed.

2. The HSI goals and considerations were arranged sequentially based upon the location in the acquisition life cycle.

3. The unique and/or the more often iterative activities required to collect HSI data were identified.

4. Data types were translated into language across the HSI domains, targeting clearly specified requirements and acquisition documents as they evolve (with the understanding that all data converges toward specifications).

5. Data collection activities were linked with the standardized professional activities and process titles (e.g., Initial HSI Assessment, Hazard Analyses, Cognitive Task Analyses) that need to be executed by HSI practitioners in the collection of valid, reliable, and accurate HSI data.

Step 5: Synthesis of the HRLs with the Human View

The output from step 4 of the HRL development was synthesized with the Human View, cross-referenced with the HSI Integrated Framework Version 1.3, and entered into a Microsoft Excel Workbook. The HRL framework is summarized in Table 8, with the much more detailed spreadsheet included in Appendix F.

Table 8. Human Readiness Level Framework Overview

Human Readiness Level	***Description***
1. Activation of Human Systems Integration: base-lining and commitment.	Lowest level of socio-technical readiness. HSI infrastructure is setup within Systems Engineering planning. Total system analysis from both functional relationship and organizational perspectives occurs. Activity examples include front-end analyses, preliminary functional allocation, and initial HSI assessment and plan.

2. Human Systems Integration analysis suite in support of component technology development.	Significant HSI input to acquisition development and documentation occurs. Activity examples include initial human-machine interface assessment, generation of Target Audience Description, and threat/hazard assessment.
3. Component human touch point resolution (i.e., human-system interaction, to include hardware and software): refining requirements thresholds.	Multiple needs analyses and studies are conducted in support of requirement definitions. HSI domain assessments inform ongoing development actions, as well. Activity examples include human-in-the-loop analyses, sub-system hazard analysis, and HSI plan update and revision.
4. Component human touch point engineering parameters and human performance indicators.	Iterative evaluation and analysis of each HSI domain takes place and provides critical items of consideration bearing on system design. Activity examples include usability testing, development of human-centered source selection, and updating the human-machine interface assessment.
5. Limited system human performance parameters/demonstration.	Various HSI assessments and testing are performed to support the significant increase in fidelity of breadboard technology. This includes supporting "high fidelity" laboratory integration of components. Activity examples include examining safety and occupational health design features and cognitive task analyses.
6. Field (relevant environment) validation of human performance prototypes.	Representative model or prototype system is tested in a relevant environment. Evaluations of human performance embedded in demonstration system occur and HSI predictive models are updated. Activity examples include testing human reliability and usability of prototype in a high-fidelity laboratory environment or in simulated operational environment.

7. Final Developmental Test & Evaluation/human performance parameters.	Significant HSI participation in system test events occurs. Iterative evaluation and analysis of each HSI domain continues as well. Activity examples include error and fault analysis to cover human error performance, equipment operability, safety procedures, and error recovery mechanisms.
8. Operational Test & Evaluation/human performance parameters.	Special human-centric analyses are conducted to update thresholds, objectives, and evolving criteria for Operational Test & Evaluation. Iterative evaluation and analysis of each HSI domain continues as well. Activity examples include system hazard analysis and HSI domain tradeoff studies.
9. Sustainment: Initiation of capability gap feedback cycle.	Extensive and iterative review and verification of fielded system begins, as well as post-product improvement evaluations for the next incremental builds. Activity examples include post-fielding training evaluation analysis and sustaining a hazard analysis for the fielded system.

The HSI Integrated Framework Version 1.3 was developed by the U.S. Navy's Space and Naval Warfare Systems Command to provide specific guidance on how to integrate HSI processes, products, and tools into Defense Acquisition (Risser, Belk, Smillie, Gepp, 2009). The HSI Integrated Framework Version 1.3 was used specifically to expand the HRL framework with any relevant detail not previously included. This allowed the final decisions to be made regarding the HRL's functional structure, processes, and intent.

C. LINKING THE HRL FRAMEWORK WITHIN THE ACQUISITION LIFE CYCLE

The intent was for each HRL to provide a risk management metric that follows a scale from 1 (*HSI base-lining & commitment*) to 9 (*capability gap feedback cycle*). Risk, for purposes of HRLs, is mitigated by professional analytical and managerial activities

that link critical items of consideration to domain-specific design decisions, including well-informed tradeoffs. A program determined to be at HRL-1 is at the lowest level of HSI readiness (thus, highest level of HSI risk), where the initial activation of HSI commitment and processes occurs. By the time the program has reached HRL-9, it has progressed through significant HSI analyses, requirement threshold refinements, field validations of human performance prototypes, and extensive developmental and operational Test and Evaluation (T&E) of human performance parameters. Ultimately, a program's human-centered maturity is achieved through the performance of HSI activities which address the consideration of end-users and other stakeholders in the specification, development, and operation of a system.

Each HRL level provides a description of the type of actions required to take the next step towards increasing the socio-technical maturity of a program with respect to those milestone-sensitive phases in a technology's life cycle. For instance, the designated criterion threshold to be met at Milestone A in the Defense Acquisition Life Cycle Management System is HRL-2; HRL-6 should be achieved prior to Milestone B; and HRL-8 prior to Milestone C. Figure 3 illustrates the HRL milestone progression below (the milestones are also discussed in more detail in Appendix C).

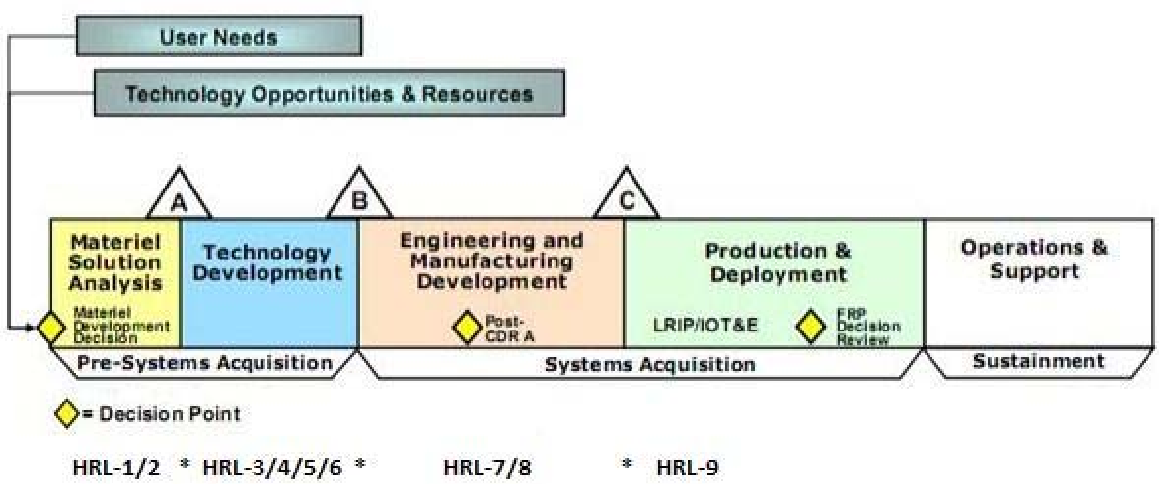

Figure 3. HRL Milestone Progression in the Defense Acquisition Life Cyle (After DoDI 5000.02, 2008)

By structuring appropriate sequencing of HSI activities and tracking the progress of HSI planning and execution, the HRL distinguishes itself as a significant risk management tool for process owners and decision makers in Defense Acquisition. Unlike TRLs where technology maturity descriptors serve as the basis for level assignment, the HRL functions by basing its HSI-related risk and maturity level off of the execution and outcome of those milestone-sensitive management and analytical activities that have been designated in each progressive HRL. Higher HRL levels are intended to be consistent with more complete specification, including the effects of tradeoff decisions. This also serves to differentiate the HRL from the Human View. For instance, the Human View has been tailored to architectural models and serves as a repository for required HSI data. It does not, however, provide the data. It is only by doing the unspecified and carefully crafted data collection and analyses delineated within tools such as the HRL that HSI data can be produced.

D. SUMMARY

This chapter described the process by which the Human Readiness Level was developed. The next chapter builds upon these efforts by describing a subject matter expert (SME) evaluation of the HRL. The focus of this initial evaluation will be on the HRL framework’s overall worth and usability.

IV. HUMAN READINESS LEVEL EVALUATION

A. BACKGROUND

In order for the HRL to be incorporated within DoD as a legitimate HSI planning tool and complementary (HSI-specific) metric in program risk management structures, it is necessary for it to first be evaluated and scrutinized by the community to which it has been developed for. This chapter describes an initial evaluation of the HRL framework by SMEs familiar with HSI and the DoD acquisition process.

B. METHODOLOGY

1. Instrument

A questionnaire was designed to gain feedback as to the overall worth and potential (i.e., accuracy, ease of use, completeness) of the HRL framework described in the previous chapter. The questionnaire consisted of 51 items divided into five separate groups. The first four grouping of items were designed to obtain feedback on the HRL's recommended milestone progression in the Defense Acquisition Life Cycle. For instance, HRL-2 is the criterion threshold to be met at Milestone A, therefore the first set of items pertained to HRLs 1 and 2. The last group of items concerned the proposed categories for future HRL framework efforts. Both the HRL framework and the evaluation instrument can be viewed in Appendix F and G respectively.

Data were gathered from participants' responses to the HRL review questionnaire based on their ratings of agreement from the five-point Likert scale ranging from "strongly agree" to "strongly disagree." The corresponding responses to the statements were converted to a numerical value ranging from 1 to 5 (1–"strongly agree" to 5–"strongly disagree"). In addition, within all five sections, the participant had the opportunity to make open-ended comments.

2. Participants

To obtain feedback from SMEs, the selection criteria for inclusion in the study was that the participants had to have experience and/or graduate level training in both HSI and Defense Acquisition. Consideration was given to focusing solely on the professionals working in these areas within the Air Force. This was due to the Air Force HSI community being accessible to the researcher. However, because of the limited expertise in this combined area, it was decided that the evaluation should be expanded to other services. Therefore, the questionnaire was distributed to 42 individuals within DoD, as well as one individual from the Canadian military. Because the SMEs served as participants *to* the research and were not subjects *of* the research, the Naval Postgraduate School's Institutional Review Board (IRB) determined the study protocol did not require IRB involvement.

C. RESULTS

Out of the 43 identified SMEs, a total of 15 HRL evaluations were returned (a 35% response rate). Of those who responded, one-third represented SMEs from the Air Force (N=5), while the remaining two-thirds consisted of respondents from other branches of the military (Army=2, Navy=4, Marines=2, Coast Guard=1, Canadian military=1). As the HRL framework was developed by two Air Force individuals, it was important to examine whether there were differences in the levels of satisfaction with the system between Air Force, and non-Air Force respondents. Table 9 summarizes the mean (and standard deviation) of the levels of satisfaction for five groups of items. It can be seen that the level of satisfaction of both Air Force and non-Air Force affiliated respondents improved with each higher level of the HRL framework.

Table 9. Rating of Agreement Summary for the SME Evaluation of the HRL Framework (1– "Strongly Agree" to 5 – "Strongly Disagree")

SME Evaluation Report						
Affiliation		HRLs 1/2	HRLs 3/4/5/6	HRLs 7/8	HRL-9	Proposed Categories
Air Force	Mean	3.04	2.76	2.49	2.49	2.16
	Std. Deviation	0.66	0.63	0.54	0.54	0.21
	N	5	5	5	5	5
Other	Mean	2.33	2.05	1.97	1.88	1.89
	Std. Deviation	0.48	0.39	0.37	0.38	0.33
	N	10	9	9	9	8
Total	Mean	2.57	2.30	2.15	2.10	1.99
	Std. Deviation	0.63	0.51	0.48	0.52	0.31
	N	15	14	14	14	13

The Mann Whitney U test (the non-parametric equivalent of the between subjects t-test) was used to assess whether there was a significant difference between Air Force affiliated participants, and those from other services. This analysis was carried out by examining the mean level of satisfaction for the items corresponding to each of the five sections of statements.

Although the non-Air Force affiliated respondents were more satisfied in each category, the difference between the two groups was only significant for the items associated with HRLs 3 to 6 ($Z= 2.0$, $p<.05$).

The Friedman's rank sign test (the nonparametric equivalent of the repeated measures Analysis of Variance) was used to assess whether there were significant differences in the satisfaction of participants with each of the four groups of HRLs. The test was found to be significant (chi square= 9.0, df= 3, $p<.05$). The respondents were significantly more satisfied with the higher HRLs than the lower HRLs.

A summary of the open-ended comments made by the respondents is provided below (see Appendix I for complete list of all of the comments made).

HRLs 1 and 2

For the first section of statements regarding HRLs 1 and 2, many participants stated that both HRLs seemed reasonably aligned with the acquisition timeline and function. However, in regards to whether any critical information was missing, many commented that acquisition programs will likely require activities or information not necessarily found in this first version of the framework. Typical comments included:

"These timings are probably program-dependent, but they seem reasonably aligned with the DODI 5000.02 timeline…"

"We don't know what we don't know. We may find that there are critical drivers that are not under our purview or within our awareness on any given program…"

HRLs 3, 4, 5, and 6

Many comments made within this section cited a need for more detail and better defined descriptions. Typical comments made were:

"Stating HRLs 3-5 all should occur "as soon as possible after MS A" does not help discriminate between the three. Timing for activity completion should be more defined."

"Descriptors should better distinguish maturity levels, particularly HRLs 3 & 4."

"Reference to "component" in HRLs 3&4 can mislead that system level was bypassed or circumvented."

HRLs 7 and 8

Of the various comments regarding HRLs 7 and 8, most were specific recommendations for improving different aspects of the HRL framework. These comments included:

> *"Need to find a way to take findings from DT&E and inform / support OT&E test readiness evaluation / report. Almost all HRL testing can be accomplished unobtrusively in DT&E and in enough detail to know what to expect in OT&E. HRL determination in OT&E will have to be a natural outcome from the actual tests—it must be unobtrusive."*

> *"The analysis by CDR for HRL-7 needs to be pretty comprehensive as the design is pretty much locked in after this point and changes become difficult to influence/implement. Appears activities for HRL-8 should be better tailored toward what resulted from DT&E, and how will deficiencies be addressed prior to OT&E."*

HRL-9

This section provided a limited amount of comments, and the comments did not appear to be centered around any particular theme. Example comments included:

> *"Recommend this HRL/description be aligned with Post Implementation Review."*

> *"It is important to include feedback throughout the entire acquisition process, not just during HRL 9."*

Proposed Categories

Each of the seven proposed categories contained comments that indicated relative satisfaction and agreement. Typical comments made for each proposed category include the following:

Acquisition & Sustainment Toolkit Linkages

"Since Logistics considerations should, like manpower and training issues, be dealt with early, it is not unlikely that much lower HRL levels could be influenced by the ASTK."

Integration Notes and Comments

"Agreed, additional details will be especially useful for individuals tasked with HSI that are not very familiar with it or with the acquisition process."

Target Documents

"Agreed, individuals can go look at those documents for additional detail on program."

"Recommend considering list of target documents for NEXT phase here as well to highlight upcoming tasks for planning purposes."

Action OPR

"There should be a program office OPR, a Sponsor/MAJCOM OPR, and an HSI OPR."

"Especially when individuals move on, it is nice to have a POC to go back to or identify that the work has been in process."

References

"Will provide information to individuals performing the tasks on exactly what they need to do and where to go to find information."

"Consider hyper linking or a separate reference database/dictionary."

Products of Activity

"Strongly agree… for building off of effort in next HRL or activity"

Rough Cost Estimate

"This provides PM with information on the cost of doing the HSI at each level/activity for a program."

"This will allow PM to pick and choose the most important activities based on budget restrictions."

D. DISCUSSION

In general, larger sample sizes permit greater confidence in the results and can increase the probability of uncovering a wide range of underlying issues being studied. However, as stated by Krosnick (1999): "*recent research has shown that surveys with very low response rates can be more accurate than surveys with much higher response rate*" (p. 540). The representativeness is more important than the sample size. Given that there is not a large number of individuals within DoD who are experienced in both acquisition and HSI, it was not possible to obtain a large number of responses from the 'right' people. Valuable insight and key information was still gleaned from a large proportion of the community who will be using the HRL framework. The following paragraphs discuss the findings from the quantitative and qualitative data.

HRLs

The agreement ratings and comments regarding the four separate groups of HRLs indicated that the respondents were generally satisfied with the framework. However, a number of suggested changes were made. For the first group of HRLs 1 and 2, the typical concern was that the framework would likely require more activities or information to be truly complete. This was not unexpected, particularly because of the sheer amount of actions and activities needed to address all HSI domains. Although, the intent is to include an exhaustive list of HSI activities within the HRL framework, the list is understandably not yet complete in this first version of the framework.

For the remaining three groups (HRLs 3/4/5/6, HRLs 7/8, and HRL 9), most comments made by the SMEs cited a need for more detail and better defined descriptions. Of particular importance was the timing of HSI activities contained within each separate HRL. The concern was that the schedule for activity completion was not always clear. For example, currently the HRL framework states that HRLs 3 through 5 should all occur "as soon as possible after MS A, prior to MS B." This statement of timing, according to

one SME, did not help to discriminate between the three HRLs. Future improvements will need to focus on the explicit delineation of HRLs and their descriptions with regards to acquisition timing and milestone events.

Other findings involved significant differences in the satisfaction of participants with each of the four groups of HRLs. Specifically, the Friedman's rank sign test revealed that as the levels within the HRL framework increased, so did the respondents' level of satisfaction. However, other than the ratings of agreement that were received, the open-ended comments did not reveal any distinctive reasoning for the SMEs' preference of the higher HRLs.

Taken at face value, their lower satisfaction of the earlier HRLs could simply indicate more effort and research should be placed on these levels. However, this would ignore other potential explanations worthy of consideration. For instance, Krosnick (1999) differentiates between two different strategies for responding to questionnaire items: optimizing and satisficing. Optimizing requires the respondent to put forth cognitive effort in order to generate the optimum answer. Conversely, when using a satisficing strategy, rather than expending the effort to generate optimal answers, respondents may compromise their standards and expend less energy. Satisficing is especially common when the respondents are required to answer a long series of questions on a wide range of topics (as with the HRL evaluation). Therefore, it is very possible that although the respondents were initially motivated to provide high-quality; optimized feedback at the beginning of the HRL evaluation, they may have become increasingly fatigued as the questionnaire progressed and shifted to a satisficing response strategy.

Another interesting finding was that non-Air Force affiliated respondents were more satisfied in each category of the HRL framework (although the difference was only significant for the items in HRLs 3 to 6). Although the reason for this finding is difficult to ascertain without conducting post interviews, one reason could be that the HRL concept originated within the Air Force. Being more familiar with the idea of an HRL, the Air Force SMEs likely had a vested interest and were more critical in their responses.

Proposed Categories

The final section of the HRL evaluation was focused on the eight proposed categories for future framework development efforts. All eight categories received many “strongly agree” and “agree” ratings from the SMEs. Along with several open-ended comments, the general feeling suggested that the proposed additions to the HRL framework is very relevant and will be useful once defined and fused into the HRL framework matrix. Of all of the proposed additions, the Rough Cost Estimate category received the most attention (i.e., number and length of comments). However, this was not surprising due to the cost-driven nature of most acquisition environments.

E. SUMMARY

The results of this evaluation suggested relative agreement among SMEs that this first iteration of the HRL concept, once fully developed, will serve as a valuable HSI planning tool and complementary (HSI-specific) metric in program risk management structures. In order to improve the framework, many SMEs recommended expanding the HRL’s list of activities to account for a more diverse variety of programs that exist in acquisition. Suggestions like these will be documented to form a basis of advocacy for future HRL development.

This effort has examined the overall worth of the HRL; however, it is only the first step in a continuing process of definition and validation. More professional scrutiny is needed. Therefore, the next chapter focuses on the validation of the HRL model when being practically applied in a current acquisition program.

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V. A CASE STUDY OF THE USEFULNESS OF THE HRL FRAMEWORK AS APPLIED TO THE GROUND CONTROL STATION MODERNIZATION PROGRAM

A. BACKGROUND

In Chapter III, the initial SME evaluation of the HRL framework was described. However, that analysis was not applied to a particular acquisition program. In this chapter, a case study of the application of the initial HRL framework was carried out as used by a SME with reference to a specific acquisition program. Specifically, the HRL framework was evaluated to assess whether it contributes to the creation and sustainment of an acquisition program's HSI Plan (HSIP). The program chosen for this case study was the U.S. Air Force Ground Control Station Modernization (GMOD) program. Background regarding the GMOD and the HSIP will be presented, followed by the evaluation of the potential usefulness of the HRL in this particular context.

1. GMOD

The GMOD program is an acquisition currently being developed in the Air Force to advance the capabilities of legacy Ground Control Stations (GCSs). GCSs are the control centers that provide the facilities for human control of remotely piloted aircrafts (RPAs). The standard GCS consists of pilot and sensor operator workstations, as well as required support equipment. Currently, the GMOD program is using a phased capabilities development approach where each phase retrofits the legacy GCS with safety-critical, mission-critical, and reliability and maintainability capabilities. The ultimate goal for the GMOD program is to significantly improve human-machine interfaces and ergonomics to increase RPA mission capability.

2. HSIP for GMOD

The key to a successful HSI acquisition strategy for GMOD is comprehensive integration across the HSI domains and also across other core acquisition and engineering

processes. Ultimately, this integration is dependent on an accurate HSIP (DAU, 2009). The HSIP is the management tool used to plan, manage, and implement HSI in an acquisition program. It is the essential plan used in identifying HSI issues and recommending resolutions for obtaining the desired capability as identified by the program's requirements and specifications (711 HPW/HPO, 2009). Employing an HSIP satisfies DoD Instruction 5000.02, where it calls for the program manager to have a plan for HSI in place early in the acquisition process to optimize total system performance, minimize total ownership costs, and ensure that the system is built to accommodate the characteristics of the user population.

The HSIP serves as an evolutionary formal document that tracks HSI execution and identifies and mitigates HSI risk as the acquisition program progresses. For the present study, the usefulness of the HRL framework to directly support this effort will be evaluated. Consideration will be given of its ability to provide a potentially exhaustive list of candidate activities to be tailored for GMOD to populate HSI Planning to inform requirements, acquisition, and sustainment documents of record. In addition, the HRL will be evaluated in its ability to provide those using the HSIP a risk management metric and process that is similar to the TRL metric and process, but that explicitly links technology development to the effective design and specification of human-centered systems in Defense Acquisition.

B. METHODOLOGY

1. Instrument

For the present study, a questionnaire was designed to gain feedback regarding the HRL's ability to effectively contribute to the creation and sustainment of an acquisition program's HSIP. Consideration was given to conducting a semi-structured interview. However, it was decided that, given the complexity of the HRL framework, a questionnaire would allow the SME to provide more thoughtful feedback, and allow him to carry out the evaluation at his convenience. The questionnaire contained a total of 16 items separated into two sections as shown in Appendix H. The first section consisted of

six Likert Scale statements that focused on the completeness and relevance of the HSI activities and categories listed within the HRL framework. The second section consisted of 10 orders of merit ranking items that were designed to gain feedback as to the relative value/importance of the current and proposed categories contained in the HRL framework when being used to support an HSIP. Within both sections, the opportunity for comments was made available.

2. Sample

The questionnaire was administered to the chief HSI practitioner working within the GMOD acquisition program. As a senior research aerospace engineer and lead for HSI transition in the Air Force Human Performance Integration Directorate, this SME was recognized to have extensive knowledge and experience in developing and managing HSIPs. Much like the evaluation that took place in Chapter IV, the expert served as a participant *to* the research and was not subject *of* the research. Therefore, the Naval Postgraduate School's Institutional Review Board determined the study protocol did not require IRB involvement

C. RESULTS AND DISCUSSION

In the first section of the HRL questionnaire, data were gathered based on the ratings of agreement from the five-point Likert scale ranging from "strongly agree" to "strongly disagree." For the most part, there was a general agreement that the HRL could serve as a beneficial tool in the development of an acquisition program's HSIP. The following statement represented the typical comments made by the case study SME:

"Agreed… the HRL provides a context of how early in the program these activities should be conducted. Ties to risk by seeing when this should be done compared to when it is planned to be done (or that it hasn't been done)."

Specifically, the expert felt the milestone-sensitive HSI activities listed in the HRL matrix could provide an effective framework for an HSI working group to tailor for

comprehensive HSI planning. Additionally, it was agreed that using the HRL framework as an HSI maturity metric can benefit HSI risk identification and management within the HSIP.

The areas of disagreement were few, but important none the less. Consistent with findings from the larger review in the previous study, the expert did not feel the HRL framework contained an exhaustive list of HSI activities to account for all program needs. Specifically, the SME felt that more activities would be necessary to ultimately manage and sustain an HSIP throughout a program's life cycle. The current activities were thought to be a good start; however, as this tool continues to mature and is used for a diverse variety of acquisition programs, more activities were felt to be needed. The following is the comment made by the SME regarding this issue:

"*I think this is a great start, but just by the limited number of activities, I think that there are other activities that we will need to add as this tool is maturing, especially as we use this prototype tool for a diverse variety of acquisition programs.*"

Other disagreement involved whether the proposed categories (i.e., column headings) for future HRL development efforts represented a complete list of the key areas of information needed to perform effective HSI Planning. A major category that was stated to be missing was some linkage to which HSI domain each of the sub-activities pertained to, or some other type of solution (e.g. color, numbering by domain, etc.) that would identify the domain. The domain links, as recommended by the expert, could introduce an even more valuable category that would calculate risk levels per domain.

In the second section of the HRL validation, data collected were based on the order of value/importance for the current and proposed categories contained in the HRL framework when being used to support an HSIP (tied values of ranking were allowed). The *HRL* category that simply designated the HRL level (i.e., 1, 1.1, 1.2, etc.) was considered most important, followed by *Products (of Activity)*, *Activity*, S*ub-Activity Detail*, *Target Documents*, *References* (tied with Target Documents), *Action OPR*, *Integration Notes/Comments* (tied with Action OPR), *Rough Cost Estimate*, and *Acquisition & Sustainment Toolkit Linkages* (did not receive a value ranking). The expert

stated that the framework categories that received higher rankings (particularly, *HRL, Products (of Activity)*, and *Activity*) was due to their ability to efficiently tie into risk management structures and not only provide a metric on which to base developmental decisions, but they also provide program managers with visible indicators of what should be done compared to when it is planned to be done. Lastly, the category of *Acquisition & Sustainment Toolkit Linkages* was not ranked because the expert did not have enough familiarity with the toolkit to pass judgment of its importance.

D. SUMMARY

The results of this case study showed that the responses of a SME considering the usefulness of the HRL framework with reference to a particular acquisition program were consistent with findings from the study reported in the previous chapter. The SME thought the HRL could serve as a beneficial tool in the development of an acquisition program's HSIP. The HSI practitioner who participated in this effort also considered the HRL to be a valuable HSI maturity metric that could benefit HSI risk identification and management within program risk management structures. In regards to needed improvements, the SME recommended to expand the HRL's activities to account for the diverse variety of programs that exist in acquisition. In the next and final chapter, recommendations will be made on improvements that need to be made to the HRL framework.

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VI. CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY

This thesis described the initial development of a Human Readiness Level framework, designed to complement the existing Technology Readiness Level currently being used within the Integrated Defense Acquisition, Technology, and Logistics (IDAT&L) Life Cycle Management System. Technology maturity assessment tools, such as the TRL, serve as systematic measurement systems that are used as entry and exit criteria for transitioning milestones and are integral components to program risk management structures. Yet, the TRL has proven incapable of consistently capturing the human-related aspects of technology development and their association with technology readiness.

The proposed HRL framework was developed to add clarity to technical readiness assessments by emphasizing the socio-technical attributes of system development. Specifically, the HRL aims to reduce technology risks related to the human element by ensuring the adequate incorporation of Human Systems Integration during technology maturity evaluations and by explicitly linking technology development to the effective design and specification of human-centered systems in Defense Acquisition. The HRL accomplishes this risk reduction by providing a time and milestone-sensitive roadmap of activities that: a) detail critical organizational milestones (that ensure functional commitment to HSI); and b) define HSI domain-specific data collection and analysis, and a clear process for their management. The primary measure of HSI risk and maturity level is based on the execution and outcome of those milestone-sensitive management and analytical activities that have been designated in each progressive HRL.

To evaluate the utility of the initial HRLs with the user population, two research efforts were carried out. In the first, an evaluation questionnaire designed to gain feedback as to the overall worth and potential usefulness of the HRL framework was given to 43 subject matter experts in the fields of HSI and Defense Acquisition. A total of 15 responses were obtained. Results of this evaluation indicated relative agreement

among SMEs that the first iteration of the HRL concept, once fully developed, will serve as a valuable HSI planning tool and complementary (HSI-specific) metric in program risk management structures. In order to improve the framework, many SMEs recommended expanding the HRL's list of activities to account for a more diverse variety of programs that exist in acquisition.

The second research effort was a case study regarding the usefulness of the HRL framework when applied to a specific acquisition program. Specifically, the HRL was evaluated in its ability to effectively contribute to the creation and sustainment of the acquisition program's HSI Plan for the Ground Control Station Modernization. Results of this SME evaluation suggested a general agreement that the HRL framework could serve as a beneficial tool in the development of an acquisition program's comprehensive HSIP. Consistent with findings from the previous evaluation, the SME did not feel that the HRL framework contained all of the necessary HSI activities to account for all program needs. The feedback and lessons learned from both studies were documented and will form the basis for future HRL development efforts. Recommendations for improvements to the HRL framework are provided in the next section.

B. RECOMMENDATIONS AND FURTHER RESEARCH

Areas of particular importance that need to be addressed in the next iteration of the HRL framework are:

1. Link HRLs to Cost Estimation Processes

In the context of a competitive cost, schedule, and performance-driven acquisition enterprise, accurately funding HSI initiatives continues to be a critical component. Often, program requirements are inappropriately funded because the costs involving HSI-specific data collection and analysis were not estimated in advance. Such exclusions produce cost overruns, schedule delays, and deficiencies in performance that have considerable impact on the eventual total life cycle cost. Therefore, continued research must focus on linking HRLs to acquisition cost estimation processes. Specifically, efforts should concentrate on detailing how HRLs establish a basis for defining HSI-specific cost

estimation factors and elements paralleling Work Breakdown Structure links to system components. This will effectively “fund the requirement” by directly informing Planning, Programming, Budgeting, and Execution processes (employed by DoD for strategic planning and resource allocation).

2. Standardize HRL Metrics Within Technology Transition

The DoD S&T community is tasked with ensuring that technologies are mature when DoD’s acquisition community takes over and integrates the technologies into weapon systems. This transition involves management and funding responsibilities to gradually shift from the lab to the product line. In order to support this transition with significant HSI influence, continued research should focus on connecting HRLs to Technology Transition Agreements. Specifically, efforts should define how HRLs articulate external dependencies on technology base projects and provide exit criteria for the technology to transition into the acquisition program (i.e., HSI metrics). This will provide S&T and acquisition program managers with demonstrated knowledge about the human-specific readiness and the potential risks of including the technology on a weapons program.

3. Define HRL Assessment Procedures

A standard repeatable method for determining the HRL achieved by a given technology must exist if the HRL is to be effectively used and consistently trusted within Defense Acquisition. Therefore, in a later stage of HRL development, a formal, systematic, and explicit process should be created for risk management and HRL reporting. The process will need to define how a measure is obtained and how to assign each HRL as an assessed program achievement value and risk management metric. Ultimately, this will be a vital step towards joining TRLs in program risk management structures within DoD.

C. CONCLUSION

Although HSI is a fundamental component of a total systems approach, the successful integration of HSI into systems engineering and acquisition life cycles continues to be a challenge. Methodologies and tools, such as the HRL framework, are needed to enhance human/system performance, maximize operational effectiveness, and prevent cost overruns. It is recognized that further development and evaluation of the HRL concept is required. However, the initial framework presented in this thesis takes that first step towards providing acquisition professionals a comprehensive guide that ensures human-centric priorities are addressed throughout all phases and milestones of Defense Acquisition.

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APPENDIX A. HARDWARE TRL DEFINITIONS, DESCRIPTIONS, AND SUPPORTING INFORMATION

Hardware TRL Definitions, Descriptions, and Supporting Information (DoD, 2009)

TRL	Definition	Description	Supporting Information
1	Basic principles observed and reported.	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development (R&D). Examples might include paper studies of a technology's basic properties.	Published research that identifies the principles that underlie this technology. References to who, where, when.
2	Technology concept and/or application formulated.	Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative, and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies.	Publications or other references that outline the application being considered and that provide analysis to support the concept.
3	Analytical and experimental critical function and/or characteristic proof of concept.	Active R&D is initiated. This includes analytical studies and laboratory studies to physically validate the analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.	Results of laboratory tests performed to measure parameters of interest and comparison to analytical predictions for critical subsystems. References to who, where, and when these tests and comparisons were performed.
4	Component and/or breadboard validation in a laboratory environment.	Basic technological components are integrated to establish that they will work together. This is relatively "low fidelity" compared with the eventual system. Examples include integration of "ad hoc" hardware in the laboratory.	System concepts that have been considered and results from testing laboratory-scale breadboard(s). References to who did this work and when. Provide an estimate of how breadboard hardware and test results differ from the expected system goals.
5	Component and/or breadboard validation in a relevant environment.	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so they can be tested in a simulated environment. Examples include "high-fidelity" laboratory integration of components.	Results from testing a laboratory breadboard system are integrated with other supporting elements in a simulated operational environment. How does the "relevant environment" differ from the expected operational environment? How do the test results compare with expectations? What problems, if any, were encountered? Was the breadboard system refined to more nearly match the expected system goals?

6	System/subsystem model or prototype demonstration in a relevant environment.	Representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high-fidelity laboratory environment or in a simulated operational environment.	Results from laboratory testing of a prototype system that is near the desired configuration in terms of performance, weight, and volume. How did the test environment differ from the operational environment? Who performed the tests? How did the test compare with expectations? What problems, if any, were encountered? What are/were the plans, options, or actions to resolve problems before moving to the next level?
7	System prototype demonstration in an operational environment.	Prototype near or at planned operational system. Represents a major step up from TRL 6 by requiring demonstration of an actual system prototype in an operational environment (e.g., in an aircraft, in a vehicle, or in space).	Results from testing a prototype system in an operational environment. Who performed the tests? How did the test compare with expectations? What problems, if any, were encountered? What are/were the plans, options, or actions to resolve problems before moving to the next level?
8	Actual system completed and qualified through test and demonstration.	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation (DT&E) of the system in its intended weapon system to determine if it meets design specifications.	Results of testing the system in its final configuration under the expected range of environmental conditions in which it will be expected to operate. Assessment of whether it will meet its operational requirements. What problems, if any, were encountered? What are/were the plans, options, or actions to resolve problems before finalizing the design?
9	Actual system proven through successful mission operations.	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation (OT&E). Examples include using the system under operational mission conditions.	OT&E reports.

APPENDIX B. SOFTWARE TRL DEFINITIONS, DESCRIPTIONS, AND SUPPORTING INFORMATION

Software TRL Definitions, Descriptions, and Supporting Information (DoD, 2009)

TRL	Definition	Description	Supporting Information
1	Basic principles observed and reported.	Lowest level of software technology readiness. A new software domain is being investigated by the basic research community. This level extends to the development of basic use, basic properties of software architecture, mathematical formulations, and general algorithms.	Basic research activities, research articles, peer-reviewed white papers, point papers, early lab model of basic concept may be useful for substantiating the TRL.
2	Technology concept and/or application formulated.	Once basic principles are observed, practical applications can be invented. Applications are speculative, and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies using synthetic data.	Applied research activities, analytic studies, small code units, and papers comparing competing technologies.
3	Analytical and experimental critical function and/or characteristic proof of concept.	Active R&D is initiated. The level at which scientific feasibility is demonstrated through analytical and laboratory studies. This level extends to the development of limited functionality environments to validate critical properties and analytical predictions using non-integrated software components and partially representative data.	Algorithms run on a surrogate processor in a laboratory environment, instrumented components operating in a laboratory environment, laboratory results showing validation of critical properties.
4	Module and/or subsystem validation in a laboratory environment (i.e., software prototype development environment).	Basic software components are integrated to establish that they will work together. They are relatively primitive with regard to efficiency and robustness compared with the eventual system. Architecture development initiated to include interoperability, reliability, maintainability, extensibility, scalability, and security issues. Emulation with current/legacy elements as appropriate. Prototypes developed to demonstrate different aspects of eventual system.	Advanced technology development, stand-alone prototype solving a synthetic full-scale problem, or standalone prototype processing fully representative data sets.

TRL	Definition	Description	Supporting Information
5	Module and/or subsystem validation in a relevant environment.	Level at which software technology is ready to start integration with existing systems. The prototype implementations conform to target environment/interfaces. Experiments with realistic problems. Simulated interfaces to existing systems. System software architecture established. Algorithms run on a processor(s) with characteristics expected in the operational environment.	System architecture diagram around technology element with critical performance requirements defined. Processor selection analysis, Simulation/Stimulation (Sim/Stim) Laboratory buildup plan. Software placed under configuration management. Commercial-of-the-shelf/government-off-the-shelf (COTS/GOTS) components in the system software architecture are identified.
6	Module and/or subsystem validation in a relevant end-to-end environment.	Level at which the engineering feasibility of a software technology is demonstrated. This level extends to laboratory prototype implementations on full-scale realistic problems in which the software technology is partially integrated with existing hardware/software systems.	Results from laboratory testing of a prototype package that is near the desired configuration in terms of performance, including physical, logical, data, and security interfaces. Comparisons between tested environment and operational environment analytically understood. Analysis and test measurements quantifying contribution to system-wide requirements such as throughput, scalability, and reliability. Analysis of human-computer (user environment) begun.
7	System prototype demonstration in an operational, high-fidelity environment.	Level at which the program feasibility of a software technology is demonstrated. This level extends to operational environment prototype implementations, where critical technical risk functionality is available for demonstration and a test in which the software technology is well integrated with operational hardware/software systems.	Critical technological properties are measured against requirements in an operational environment.
8	Actual system completed and mission qualified through test and demonstration in an operational environment.	Level at which a software technology is fully integrated with operational hardware and software systems. Software development documentation is complete. All functionality tested in simulated and operational scenarios.	Published documentation and product technology refresh build schedule. Software resource reserve measured and tracked.
9	Actual system proven through successful mission-proven operational capabilities.	Level at which a software technology is readily repeatable and reusable. The software based on the technology is fully integrated with operational hardware/software systems. All software documentation verified. Successful operational experience. Sustaining software engineering support in place. Actual system.	Production configuration management reports. Technology integrated into a reuse “wizard.”

APPENDIX C. MANAGEMENT OF TECHNOLOGY MATURITY IN THE DEFENSE ACQUISITION MANAGEMENT SYSTEM

The Defense Acquisition Management System, as stated in the 2009 *Defense Acquisition Guidebook (DAG)*, exists to manage the Nation's investments in technologies, programs, and product support necessary to achieve the National Security Strategy and support the United States Armed Forces. More specifically, it establishes a simplified and flexible management framework for translating capability needs and technology opportunities, based on approved capability needs, into stable, affordable, and well-managed acquisition programs that include weapon systems, services, and automated information systems (AISs) (DoDI 5000.02, 2008).

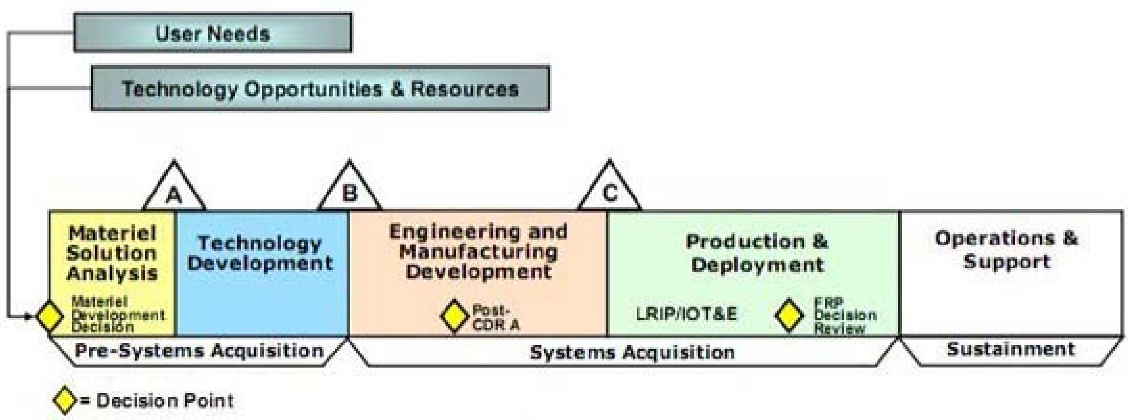

Figure 4. Integrated Defense Acquisition, Technology and Logistics Life Cycle Management System (After DoDI 5000.02, 2008)

Figure 4 depicts the evolution of technology in the DoD Acquisition Life Cycle. This process, beginning with User Needs and Technology Opportunities, uses Joint Concepts, integrated architectures, and an analysis of doctrine, organization, training, materiel, leadership and education, personnel, and facilities (DOTMLPF) to define needed capabilities and to guide the development of affordable systems through five subsequent phases:

1. Materiel Solution Analysis (MSA)
2. Technology Development (TD)
3. Engineering and Manufacturing Development (EMD)
4. Production and Deployment (PD)
5. Operations and Support (OS)

Of the five phases, the first four place emphasis on technology and product development. During these early stages a new technology undergoes research and development, integration into systems, and finally the manufacture and distribution in weapon system form. The last phase, Operations and Support, attends to the system after it has been fielded and represents the majority of the actual time a system and its integrated technology must be managed (Nolte, 2008).

In DoD acquisition, a crucial part of overall program management is the management of technology maturity and mitigation of technology integration risk. Therefore, per DoD Instruction 5000.02 *Operation of the Defense Acquisition System,* objective evaluations of technology maturity are required to be routine aspects throughout the entire acquisition life cycle. The evaluation, officially referred to by DoD as the Technology Readiness Assessment (TRA), is the formal, systematic, metrics-based process used to assess the maturity of critical hardware and software technologies to be used in DoD systems. The TRA is conducted by an Independent Review Team (IRT) of subject matter experts (SMEs) who use the TRL as the metric to assess technology maturity.

All DoD acquisition programs going through the Defense Acquisition System must have a formal TRA completed at Milestone B, which is normally the formal initiation of an acquisition program, and also at Milestone C. However, assessments of technology readiness or TRA-like activities other than the formal TRAs at Milestones B and C take place over the acquisition life cycle.

Using information and guidance found in DoD's 2009 *Technology Readiness Assessment Deskbook*, the following paragraphs summarize how the knowledge

concerning technology maturity evolves over time within acquisition and discusses the mandated TRL levels that must be met to progress through the acquisition life cycle.

A. EARLY EVALUATIONS OF TECHNOLOGY MATURITY

In the Materiel Solution Analysis phase, an Analysis of Alternatives (AoA) is conducted to identify potential materiel solutions, based on a cost-benefit analysis. While this is occurring, early Systems Engineering (SE) activities, such as the proposed Engineering Analysis of Potential System Solutions, are conducted. The possible materiel solutions are then expected to undergo an Early Evaluation of Technological Maturity, provided sufficient technical information exists to support such an evaluation. This evaluation is an activity separate from the formal TRA and is conducted shortly before Milestone A.

This body of work—the AoA, the early SE, and the Early Evaluation of Technological Maturity—forms the basis of the Technology Development Strategy (TDS) for evaluating the technology options in the materiel solution to the capability need identified in the approved Initial Capabilities Document (ICD). DoD relies on the TDS to show how the technologies (those known by Milestone A to be critical for the successful realization of the chosen materiel solution) will be demonstrated in a relevant environment (equivalent to TRL 6) before they are used in Engineering and Manufacturing Development. If the AoA and early SE work does not result in sufficient technical information to support adequate evaluation of technology maturity, acquisition programs are still expected to have an evaluation completed prior to Milestone A so that critical technologies can be matured during the subsequent Technology Development phase.

The TRA Deskbook states a recommended best practice is to use the results of this early evaluation of technology maturity as follows:

- To provide a basis for modifying the requirements if technological risks are too high.

- To support the development of Technology Maturity Plans (TMPs) that show how all likely critical technologies will be demonstrated in a relevant environment before preliminary design begins at the full system level.
- To refine the TDS.
- To inform the test and evaluation (T&E) community about technology maturity needs.
- To ensure that all potential critical technologies are included in the program's risk management database and plan.
- To establish Technology Transition Agreements (TTAs) to articulate external dependencies on technology base projects and to define the specific technologies, technology demonstration events, and exit criteria for the technology to transition into the acquisition program.

Ultimately, the early evaluation of technology maturity conducted at or shortly before Milestone A helps evaluate technology alternatives and risks and, by doing so, helps the acquisition Program Manager (PM) refine the plans for achieving mature technologies before Milestone B approval is sought. However, it is worth noting that this early evaluation of technology maturity is not a replacement for the Milestone B TRA (DoD, 2009).

B. MILESTONE B TRA

Throughout the beginning MSA and Technology Development phases, the DoD science and technology (S&T) community is tasked with ensuring that technologies are mature when DoD's acquisition community takes over and integrates the technologies into weapon systems. This transition occurs at Milestone B which begins the EMD phase and, as mentioned earlier, normally marks the formal initiation of an acquisition program. To avoid programs from entering the EMD phase of the Defense Acquisition System with immature technologies, Title 10 United States Code (U.S.C.) Section 2366b requires, in part, that the Milestone Decision Authority (MDA) certify that the technology

in Major Defense Acquisition Programs (MDAPs), including space MDAPs, has been demonstrated in a relevant environment (TRL 6) before Milestone B approval. In addition, while 10 U.S.C. 2366b is only binding for MDAPs, the DoD is also requiring Major Automated Information System (MAIS) acquisitions to meet the same technology maturity standard at Milestone B. The formal TRA process and report serves as the basis of the MDA certification.

In cases where the technology in the program has not been demonstrated in a relevant environment, the MDA is allowed to waive the certification requirement if it determines that such a requirement would hinder the DoD’s ability to meet critical national security objectives. However, as a matter of practice, such waivers will only be granted in extraordinary circumstances. In fact, DoDI 5000.02 requires Request for Proposal (RFP) language that prevents the award of an EMD contract if it includes technologies that have not been demonstrated to be mature. Therefore, a generic TRA not based on a planned technical solution is not acceptable by DoD. The TRA must be based on the technologies in the system and must be performed on all the competitors’ proposals in a source selection.

C. MILESTONE C TRA

Milestone C marks approval to enter Low-Rate Initial Production (LRIP) for hardware systems and limited deployment in support of operational testing for MAIS programs or for software-intensive systems that have no production components. TRL 7 or higher is the expected state of technology maturity at Milestone C.

The Milestone C TRA is conducted to reflect the resolution of any technology deficiencies that arose during EMD and it serves as a check that all critical technologies are maturing as planned. By the time an acquisition program reaches Milestone C, all critical technologies are expected to have appropriate advancements while continuing to mature through established TMPs. Any new technologies that have emerged should be identified, and their maturation plans reviewed.

For software, TRL 7 means that all source codes have been written and tested—not only as an independent module and/or component, but also as integrated into the whole system. The TRA at Milestone C is important for MAIS programs because it

- Documents successful developmental test and evaluation (DT&E).
- Examines plans for maintenance and upgrades to ensure that no new technologies are involved.
- Determines whether algorithms will transfer successfully when host platforms are moved and full-scale applications are initiated in a real operational environment.
- Identifies where new Milestone B reviews are needed for future releases to initiate efforts to improve performance and determines the architectural changes necessary to support these future releases.

APPENDIX D. IMPACT OF IMMATURE TECHNOLOGY IN DEFENSE ACQUISITION PROGRAMS

In numerous reports to Congressional Committees, the Government Accountability Office (GAO) has addressed the problems with proceeding in system development with immature technologies and has detailed the resulting cost overruns, schedule delays, and performance shortfalls that have been undermining DoD's buying power. According to the GAO, this dilemma is due in part to DoD's difficulty transitioning technologies from a technology development environment to an acquisition program. Because the acquisition community frequently pulls technologies too early, it takes on the additional task of maturing the technologies—an activity that is the primary responsibility of technology developers—at the start of an acquisition program. They further state that the start of a program ushers in a high-cost, delivery-oriented phase in which the acquisition community is supposed to be focused on integrating subsystems and working on system development and demonstration. DoD has continued to allow the acquisition community to take over this task before the S&T community considers the technologies ready for transition (GAO, 2006). The lower the level of technology readiness, the more ground must be covered to bring the technology to the point at which it can meet the intended product's cost, schedule, and performance requirements with little risk. Figure 5 illustrates this idea on the following page.

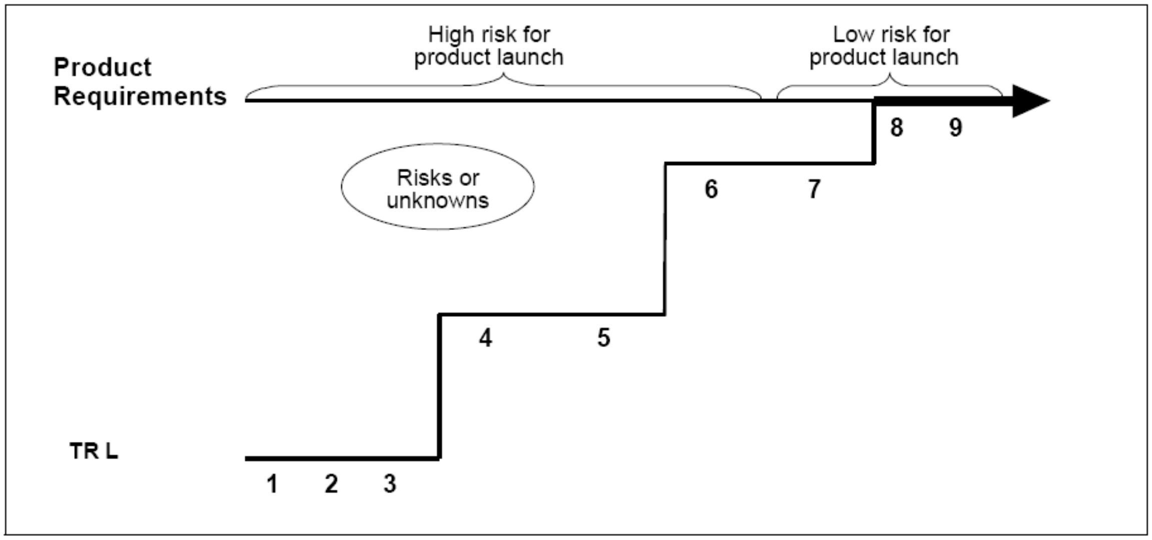

Figure 5. Using TRLs to Match Technology With Product Launch Requirements (From GAO, 1999)

The gap between the maturity of the technology and the product's requirements represents the risks or unknowns about the technology. As each succeeding level of readiness is demonstrated, unknowns are replaced by knowledge and the gap becomes smaller. Ideally, the gap is closed before a new technology is included in a new product's design (GAO, 1999).

Large, highly visible acquisition programs are by no means immune to the problems surrounding immature technology. The Joint Strike Fighter (JSF), for example, is the most expensive aircraft program in DoD and has endured multiple acquisition schedule changes in order to reduce risk. The following GAO statement found in the 2001 Joint Strike Fighter Acquisition report, illustrates how *not* meeting anticipated technology maturity can delay entry into key development phases:

> *"Last year, we testified and reported that a key objective of the program's acquisition strategy is affordability and that a part of that strategy— entering into engineering and manufacturing development with low technical risk—would not be achieved because technologies critical to meeting the program's cost and requirement objectives were projected to be at low levels of technical maturity in April 2001, the date then scheduled for awarding the engineering and*

manufacturing development contract. We stated that the program's approach was not consistent with best practices in which technologies are more fully developed before proceeding into product development… Because of concerns about the adequacy of the Joint Strike Fighter's short take-off and vertical landing flight test program, the maturity of its critical technologies, and other factors, the Fiscal Year 2001 National Defense Authorization Act directed that the contract for the aircraft's engineering and manufacturing development not be awarded until certain criteria were met" (GAO, 2001, p. 1).

The impact of immature technology can also be seen in the GAO's 2006 review of 52 major DoD weapon programs. In this review, 90 percent of the programs were found to have started with immature technologies and more than half of the programs were working with immature technologies at design review, the time when DoD acquisition policy expects the design to be stable. By the time production began, one-third of the programs still did not have mature technologies. Not surprisingly, the GAO found that DoD research, development, test, and evaluation cost estimates increased dramatically for programs having immature technologies at program start (GAO, 2006). Figure 6 shows the average cost growth of DoD programs reviewed when technologies were mature and immature at program start.

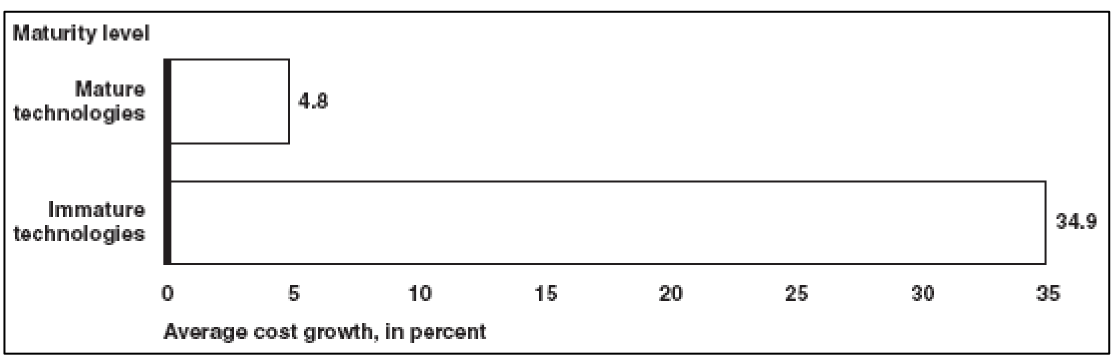

Figure 6. Average Program Research, Development, Test, and Evaluation Cost Growth From First Full Estimate (sample of 52 DoD weapon programs) (From GAO, 2006)

Programs that started with mature technologies averaged a fairly small 4.8 percent cost growth above the first full estimate, whereas programs that started with immature

technologies averaged about 35 percent cost growth. This includes some programs that experienced significantly greater cost growth. A consequence of this cost growth is that DoD typically delivers weapon systems late, reduces quantities to stay within cost estimates, shifts funds away from other projects to make up for added costs, or some combination of the three (GAO, 2006).

APPENDIX E. THE NATO HUMAN VIEW

All of the information contained in this appendix was derived from the NATO Human View Handbook, which was prepared by the NATO RTO HFM-155 Human View Workshop. The purpose of a human view is to capture the human requirements and to inform on how humans interact with systems. The Workshop panel's final set of products that composes the NATO Human View is listed below:

HV-A Concept

HV-B Constraints

HV-C Tasks

HV-D Roles

HV-E Human Network

HV-F Training

HV-G Metrics

HV-H Human Dynamics

HV-A CONCEPT

The HV-A is a conceptual, high-level representation of the human component of the enterprise architecture framework. Its purpose is to visualize and facilitate understanding of the human dimension in relation to operational demands and system components. It serves as both the single point of reference and departure to depict how the human will impact performance (mission success, survivability, supportability, and cost) and how the human will be impacted by the system design and operational context (personnel availability, skill demands, training requirements, workload and well-being). The HV-A has a close relationship with other architecture products that provide high-level concepts.

The elements of the HV-A may include:

- Pictorial depictions of the system and its human component
- High level indicators of where human system interactions may occur
- A textual description of the overall human component of the system
- A use case which describes the human process

HV-B CONSTRAINTS

Not only is the human the most important and unique system within the system-of-systems, but it can also be the weakest link or highest risk in that system. Therefore expressing the capabilities and limitations of the human in the system is required. The HV-B contains the set of data elements that are used to adjust the expected roles and tasks. It acts as a repository for different sets of constraints that may affect parameters of different views that may impact the human system. If a system requires a human interface, then the system must be designed to accommodate the human in such a way as to account for the human limitations, and to support/maintain the human to at least a minimum acceptable level.

Due to the range of information captured in the HV-B, six sub-products capturing specific subsets of data have been defined for the HV-B. These are broken into two subsets, Personnel, containing four sub products, and Human Factors, containing two sub products.

Personnel Sub Products: information about personnel available to participate in the roles:

- Manpower Projections (HV-B1)—illustrates predicted manpower requirements for supporting present and future projects that contribute to larger capabilities
    - Understand manpower forecasting to allow initial adjustments in training, recruiting, professional development, assignment and personnel management

    - Anticipate impacts (and timeframe) related to number(s) of personnel, personnel mix, Military Occupational Structure Identification (MOSIDs), Rank/level distribution, and, postings/relocation(s) of personnel
    - Ensure sufficient number of personnel with necessary Knowledge, Skills, Abilities (KSAs) are ‘ready and able’ to support fielding of future program

- Career Progression (HV-B2)—illustrates career progression as well as the essential tasks, skills, and knowledge (and proficiency level) required for a given job
    - Address impacts of alternative system and capability designs on career progression;
    - Determine jobs available given an individual’s current job and occupation;
    - Assess competencies required for each individual job; and
    - Support personnel planning by identifying availability of individuals with necessary competencies early in acquisition process

- Establishment Inventory (HV-B3)—Defines current number of personnel by rank and job within each establishment
    - Supports forecasting of trained effective strength
    - Supports predicting number of people that must be trained, recruited, etc. to fill gaps required for “out years”

- Personnel Policy (HV-B4)
    - Defines the various department policies dealing with (governing) HR issues

    - Ensures that personnel are fairly considered, properly treated, well looked after and supported in a legal, moral and ethical manner while employed with the department
    - HR documents, such as policies, doctrine, laws, benefits, pay, SOPs, etc.

Human Factors Sub Products—data related to the capabilities of the humans assigned to roles:

- Health Hazards (HV-B5)
    - Considers the design features and operating characteristics of a system that can create significant risks of illness, injury or death
    - Aims to eliminate minimize or control both short- and long-term hazards to health that occur as a result of system operation, maintenance and support
    - Hazards may include system, environmental or task hazard assessment; air quality control assessment; noise/vibration pollution evaluation; impact force, shock protection; WHIMS evaluation of tasks; radiation/LASER protection; CB protection; extremes of temperature, etc.
    - It may include aspects of survivability, i.e., limiting the probability of personal injury, disability or death of personnel in their interactions with the system. This can include providing protection from attack, and reducing detectability, fratricide, system damage, personnel injury and cognitive and physical fatigue
- Human Characteristics (HV-B6)
    - Considers the physical characteristics of an operator and movement capabilities and limitations of that operator under various operating conditions

- Aims to compare operator capabilities and limitations with system operating requirements under various conditions to match or eliminate operating capabilities
- It may include aspects such as anthropometrical/medical data; reach data; range of motion data; physical strength data; visual and auditory assessment; speed or duration of activity data; cognitive workload; working memory capacity; ability to be security cleared; personality, motivation, etc.

HV-C TASKS

The HV-C describes the human-specific activities, i.e., the tasks that have been assigned to the humans in a system over its entire life cycle. It also considers how the functions are decomposed into tasks. (The term task in this product refers to a piece of work that can be assigned to a person.)

The HV-C may also:

- Clarify the human-related functions in a system
- Provide a justification for the allocation of functions between the humans and machines
- Decompose these functions into a set of tasks that can be mapped to the roles identified in HV-D
- Describe these tasks in terms of various criteria and the KSA requirements
- Produce a task-role assignment matrix
- Depict the inter-dependencies between different tasks, particularly across functional groupings
- The information demands to perform specific tasks
- The tools required to accomplish a task
- Create interface design guideline on the basis of task requirements

The HV-C is very broad and can be used to capture all aspects of the human-related tasks in a system, including the allocation of tasks between humans and systems. This product is also closely related to the HV-D Roles, which will be described in the next section. There may be some overlap between the definition of tasks, roles and the assignment between them. More often, there may be multiple HV-C products representing different aspects of the human tasks in the architecture. In this case, the multiple products can be labeled consecutively within the HV-C context.

HV-D ROLES

The HV-D describes the roles that have been defined for the humans interacting with the system. A role represents a job function defining specific behavior within the context of an organization, with some associated semantics regarding the authority and responsibility conferred to the user in the role, and *competencies* required to do the job. The role structure can be mapped to the human task decomposition to define the organizational responsibilities, and relationships between roles can be defined which provides the basis of the organizational structure.

The HV-D may define additional attributes of a role including:

- Responsibility—a form of accountability and commitment; roles are generally defined by their responsibilities
- Authority—is the access ability of an individual user to perform a specific task
- Competencies—the quality of being able to perform; a combination of knowledge, skills and attributes; these should be trainable and measurable
- Multiplicity—a role may be performed by a human user or by many human users at the same time

The HV-D is closely related to the HV-C, as the identified tasks need to be allocated to roles, and competencies for the roles defined based on the assigned tasks.

The HV-D can also be extended to include a “concept of work” to describe the distribution of responsibilities among humans and specific requirements for those responsibilities.

HV-E HUMAN NETWORK

The HV-E captures the human to human communication patterns that occur as a result of ad hoc or deliberate team formation, especially teams distributed across space and time.

Elements of the HV-E may include:

- Role groupings or teams formed, including the physical proximity of the roles and virtual roles included for specific team tasks
- Type of interaction—i.e., collaborate, coordinate, supervise, etc.
- Team cohesiveness indicators—i.e., trust, sharing, etc.
- Team performance impacts—i.e., synchronization (battle rhythm), level of engagement (command directed)
- Team dependencies—i.e., frequency/degree of interaction between roles
- Communication/Technology impact to the team network - i.e., distributed cognition, shared awareness, common operational picture, etc.

HV-F TRAINING

HV-F is a detailed accounting of how training requirements, strategy, and implementation will impact the human. It illustrates the instruction or education and on-the-job or unit training required to provide personnel their essential tasks, skills, and knowledge to meet the job requirements. This view can also address the development of additional training programs to meet the requirements of new capabilities.

Data elements of the HV-F may include:

- As-is training resources, availability, and suitability

- Risk imposed by to-be operational and system demands
- Cost and maturity of training options for tradeoff analysis
- Address impacts of alternative system and capability designs on training requirements and curriculums
- Determine training required to obtain necessary knowledge, skills, and ability to support career progression
- Differentiation of basic, intermediate, or advance job training; operational vs. system specific training; and individual vs. team training

HV-G METRICS

The HV-G can be its own product or incorporated into another architecture metric view, such as the SV-7 (in MoDAF and DoDAF). It provides a repository for human-related values, priorities and performance criteria, and maps human factors metrics to any other human view elements. It may map high-level (qualitative) values to quantifiable performance metrics and assessment targets or it may map measurable metrics to human functions, i.e., human performance specifications. It provides the basis for any human factors assessments to underpin enterprise performance assessments and the foundation for requirements tracking and certification. For example, it may include task standards as well as performance measures.

Elements of HV-G may include:

- Human Factors Value definitions level 1…n
- Human Performance Metrics (what is to be measured)
- Target Values (what quantifiable value is acceptable)
- Key Performance Parameters
- Human Task to Metrics mapping
- Value to design element mapping
- Methods of compliance

HV-H HUMAN DYNAMICS

The HV-H captures dynamic aspects of human system components defined in other views. These are dynamic aspects in the sense that states, conditions, or performance parameters may change over time, or as a result of triggering events. It pulls together definitions from across the Human View to be able to communicate enterprise behavior. It provides inputs to human behavior and executable models that may be supported by simulation tools. There are many different human models and simulations that can be used to develop dynamic models; this view can provide stimuli and design aspects for these models.

Features of the HV-H may include:

- States (e.g. snapshots) and State Changes, e.g.,
  - Organizational/team structure
  - Task/Role assignments to people
  - Team interaction modes
  - Demands on collaboration load (e.g., need to spend effort in building shared awareness, consensus-finding, communicating)
  - Task switches/interruptions
- Conditions (e.g. triggering events or situations; scenarios)
  - Critical / frequent / representative / typical scenarios
  - Operational constraints (e.g. extensive heat stress)
  - Time conditions: sequence, duration, concurrency
- Performance outcomes (observed or predicted), e.g.,
  - Workload
  - Decision speed

- Team interaction/collaboration style
- Trust in commanders intent
- Quality of shared awareness/coordination/implicit communication

APPENDIX F. HUMAN READINESS LEVEL FRAMEWORK

The following pages contain the first iteration of the Human Readiness Level framework. The contents of the framework drew heavily upon the technical details of the NATO Human View Handbook and the Navy’s HSI Integrated Framework Version 1.3 (NATO RTO HFM-155 Human View Workshop, n.d.; Risser, Belk, Smillie, Gepp, 2009). At this point in the HRL’s evolution, only the first three columns have been fully populated. The remaining columns represent the proposed categories of future HRL developmental efforts.

HRL	Activity	Sub-Activity Detail	Acquisition &Sustainment Toolkit Linkages	Integration Notes and Comments	Target Documents (e.g. ICD or RFP)	Action OPR (generally within HSI WG)	References	Products (of Activity)	Rough Cost Estimate
HRL1= Activation of Human Systems Integration Process: Baselining & Commitment	HRL-1 activities should occur as soon as possible prior to Milestone A (MS A)								
1.1	**Program HSI commitment actions; setting up HSI infrastructure within SE planning**	**1.1.1 Appoint HSI Lead, 1.1.2 Initiate Program HSI Plan (HSIP) draft including HSI Risk mitigation process 1.1.3 Define process for continuously rolling up HSIP milestones into SEMP at proper level of resolution 1.1.4 Synchronize with SMART, and 1.1.5 Establish relationship/MOA with primary service HSI support unit**							
1.2	**Total system analysis from both functional relationship and organizational perspectives with an empahsis on system boundaries**	**1.2.1 Whole system Front End Analysis (System, System of Systems (SOS)and Family of Systems(FOS) Definition); 1.2.2 Mission Scope Analysis**							
1.3	**HSI Assessment for HRL1 (HSIA-1): Assessment based on best available solution description (in CBA, AoA, CONOPs, ICD, etc.) across all HSI domains to define level of risk in each. First priority goal is to affect design; second priority is to inform sustainment**	**1.3.1 Manpower /Workload/ Functional Allocation 1.3.2 Personnel / KSA clusters / Selection/ Retention/ Career Path 1.3.3 Training/KSAs 1.3.4 Environment 1.3.5 Survivability / Situation Awareness/ Force Protection/ Egress systems 1.3.6 Habitabiltiy / Sustained Ops/ Facilities 1.3.7 Occupational Health 1.3.8 Safety/ HFACs 1.3.9 Human Factors Engineering 1.3.10 Establish initial issues log with mitigation plans 1.3.11 Discuss and define HSI risk matrix reporting process and criteria for PM review and approval**		Provides baseline for all HSI-related activities. All domains are addressed.// Each domain dictates critical items of consideration bearing on system design depending on the (initially likely, and later definite) Human Touch Points (HTPs) in a system as it evolves. Risk, for purposes of HRLs, is mitigated by Professional analytical and managerial activities that link critical items of consideration to domain-specific design decisions, including well-informed trade-offs. Cricical initial step in HSI planning.					

1.4	**Use this as planning tool for the HSIWG to ensure maximum coordination among data-collection and analysis activities**	**1.4.1 Integrated activity worksheet for HRL1**		Worksheets should be used prior to detailing in HSIP. Several of the data collection activities are listed as rows below but others willl have to be "planned" based on specific proram needs. A critical goal should be to minimize interference with operational SMEs (minimize number of visits by different data collectiion teams when overlapping data are sought).					
1.5	**Systematic prediction of errors that could be made by the humans in the system**	**1.5.1 Human Reliability Assessment (HRA)**							
1.6	**Initial HFE analysis of projected system functions, identifying expected reliability based on human performance vs. automation. Extract lessons learned to feed back to capability requirements and feed forward to design implications**	**1.6.1 Identify HFE high drivers and lessons learned from legacy systems 1.6.2 Identify user needs and environmental constraints on human performance 1.6.3 Contribute to assessment and development of system concepts/ materiel solutions 1.6.4 Assist in development of the cost estimate based on anticipated Manpower 1.6.5 Conduct Mission Task Analysis 1.6.5.1 Develop Mission Scenarios 1.6.5.2 Conduct Mission Level Functional Analysis 1.6.5.3 Develop Design Reference Scenarios 1.6.5.4 Prelimary Function Allocation. 1.6.5.5 Conduct Mission Level Task Analysis**							

1.7	Systematic prediction of conditions inherent in normal operations (including combat) that might lead to death, disability, illness, injury, or performance deterioration. Should include a system safety engineering analysis file to document system design mitigations as hazards are identified	1.7.1 Hazard Analysis / preliminary system, safety analyses / Identify safety issues, lessons learned and drivers from legacy systems 1.7.2 Contribute to assessment and development of system concepts and materiel solutions 1.7.3 Develop Preliminary Hazard List (PHL) for each system concept and materiel solution 1.7.4 Assist in development of cost estimates based on anticipated safety activities & contributions for proposed concepts/solutions 1.7.5 Participate in Mission /Task Analysis [Contribute to TDRA while identifying drivers and requirements] 1.7.6 If munition, perform Threat Hazard Assessment (THA): 1.7.7 Generate PHL							
1.8	Identify manning needs, manpower lessons learned, and high drivers from legacy systems	1.8.1 Establish manpowr thresholds and objectives 1.8.2 Establish level and duration criterion for high sustained workload. 1.8.3 Identify manpower goals and parameters (DoD1100.4) 1.8.4 Define the human performance characteristics of the user population (based on mission and system requirements, target occupational specialties, recruitment and retention trends) 1.8.5 Contribute to assessment and development of system concepts / materiel solutions 1.8.6 Assist in development of the cost estimate based on anticipated manpower 1.8.7 Participate in Mission Task Analysis [Incorporate findings from Mission Task Analysis into initial TDRA)							

1.9	Synchronize with DoDAF	1.9.1 Coordinate with Requirements Manager (RM) on current state of OV-1 and CONOPS; 1.9.2 Begin specification of HV-A 1.9.2.1 Review information and data components required to begin populating all HVs		OV-1: operational concept graphic. Concept (HV-A)					
1.10'	Linear modeling and studies /analyses of System Approach Alternatives	1.10.1 Plan preliminary linear models 1.10.2 Negotiate with stakeholders of "what if" studies 1.10.3 Begin coordination with Man In the Loop (MIL) simulation experiments							
1.11a	Perform personnel alternatives concept development and assessments	1.11.1 Consider personnel alternatives based on FSA (CJCSM /3170.01C) 1.11.1.2 Determine impacts on cost estimates 1.11.1.3 Determine appropriate personnel approaches 1.11.1.4 Assist in development of the cost estimate based on anticipated personnel activities 1.11.2 Define the human performance characteristics of the user population (based on mission and system requirements, target occupational specialties, and recruitment and retention trends)							
1.11b	Perform personnel alternatives concept development and assessments	1.11.3 Identify personnel shortfalls 1.11.4 Use findings from the mission task analysis and other personnel assessments to identify KSAs 1.11.5 Assess personnel readiness, personnel tempo, and funding issues that may impact the ability to fill personnel requirements 1.11.6 Perform an analysis of alternatives for personnel optimization							

1.12a	Perform training alternatives concept development and assessments	1.12.1 Perform a training effectiveness evaluation on legacy systems 1.12.1.1 Provide recommendations to correct training deficiencies 1.12.1.2 Identify training deficiencies and root causes 1.12.2 Assess human performance and effectiveness of training transfer 1.12.3 Assist in development of the cost estimate based on anticipated training activities 1.12.4 Participate in Mission Task Analysis 1.12.4.1 Input mission scenarios to the training assessment 1.12.4.2 Conduct assessments to determine KSAs, learning objectives, and training requirements for the proposed materiel solution 1.12.4.2.1 Justify the training system 1.12.4.2.2 Skills and Training analysis 1.12.4.2.3 Training Requirements Analysis 1.12.4.2.4 Complete total training requirements 1.12.4.2.5 Perform a media selection analysis							
1.12b	Perform training alternatives concept development and assessments	1.12.5 Perform analysis of alternatives for training optimization 1.12.6 Technologies/cost trade-off analyses for training options 1.12.6.1 Assist in development and evaluation of the training program planning of alternatives 1.12.6.2 Consider tasks, conditions, and standards from the Functional Area Analysis							

HRL	**Activity**	**Sub-Activity Detail**	**Acquisition &Sustainment Toolkit Linkages**	**Integration Notes and Comments**	**Target Documents (e.g. ICD or RFP)**	**Action OPR (generally within HSI WG)**	**References**	**Products (of Activity)**	**Rough Cost Estimate**
HRL2=HSI analysis Suite to support component technology development	**HRL-2 activities should occur as soon as possible prior to MS A**								
2.1	**HSI Assessment ~ HRL2 (HSIA2). First priority goal is to affect design; second priority is to inform sustainment.**	**2.1 Assess HSI considerations in each Domain** **2.1.1 Manpower /Workload/ Functional Allocation** **2.1.2 Personnel / KSA clusters / Selection/ Retention/ Career Path** **2.1.3 Training /KSAs** **2.1.4 Environment/** **2.1..5 Survivability / Situation Awareness/ Kll Chain Analysis/ Force Protection/ Egress systems** **2.1.6 Habitabiltiy / Sustained Ops/ Facilities** **2.1.7 Occupational Health** **2.1.8 Safety/ HFACs** **2.1.9 Human Factors Engineering** **2.1.9.1 Define HFE Concept/Capability** **2.1.10 HSI WG review HSI Issues log and mitigaton progress** **2.1.11 HSI WG specifies and recommends risk matrix outcomes and HRL assignment to PM**		Re-Assessment based on best available Solution Description (Now to include solution alternative from AoA or Block definition and current state of CONOPs, ICD, etc.) across all HSI domains to define level of risk in each. Each domain dictates critical items of consideration bearing on system design depending on the (initially likely, and later definite) HTPs in a system as it evolves. Risk, for purposes of HRLs, is mitigated by Professional analytical and managerial activities that link critical items of consideration to domain-specific design decisions, including well-informed trade-offs. Provides baseline for all HSI-related activities. All Domains are addressed.					

2.2	Update/revise HSIP	2.2.1 Using worksheet as described in HRL-1 to update sequence of activities remaining							
2.3	Generate Target Audience Description and Airman Capabiltiy Document	2.3.1 Use findings from the mission task analysis and other personnel assessments to identify KSAs / Human Performance requirements 2.3.2 Analysis activities to define Manpower, Personnel and Training-related Human Performance parameters 2.3.3 Assess personnel / readiness, personnel /tempo, and funding issues that may impact the ability to fill Personnel requirements/current and needed AFSCs / hard to fill occupations / required KSAs 2.3.4 Derive initial Personnel requirements/[New occupational specialties (unique skill sets) /hard to fill occupations Highly qualified personnel. Determine how requirements will be met							
2.4a	Training Systems Requirements Analysis (TSRA)—The initial step in user requirements identification. It consists of mission/task analysis, training requirements identification, objectives/media analysis, and training systems basis analysis. A TSRA integrates the products of the Instructional System Development (ISD) process and the Systems Engineering (SE) process to describe the Training System to be procured. It serves as a required input to the System Training Plan. It is accomplished by the PM in coordination with the Lead Command and User Command (Aug 30, 2007 ... This TSRA process is consistent with DODD 1430.13)	2.4.1 Participate in Mission Task Analysis 2.4.2 Input mission scenarios to the training assessment//JTA reviews 2.4.3 Conduct assessments to determine KSAs, learning objectives, and /training requirements for the proposed materiel solution 2.4.3.1 Justify the training system Learning Performance and Solution Analysis 2.4.3.2 Skills and Training Analysis/Training Requirements Analysis 2.4.3.3 Complete total training requirements 2.4.4 Perform a high level media selection analysis 2.4.5.1 Perform an analysis of alternatives for training optimization 2.4.5.2 New learning Technologies Cost trade-off analyses for training options 2.4.5.3 Assist in development, and evaluation of the training / program planning 2.4.5.4 Provide descriptions, methods, and technology requirements for the training concept							

2.4b	Training Systems Requirements Analysis (TSRA)—The initial step in user requirements identification. It consists of mission/task analysis, training requirements identification, objectives/media analysis, and training systems basis analysis. A TSRA integrates the products of the Instructional SystemDevelopment (ISD) process and the Systems Engineering (SE) process to describe the Training System to be procured. It serves as a required input to the System Training Plan. It is accomplished by the PM in coordination with the Lead Command and User Command (Aug 30, 2007 ... This TSRA process is consistent with DODD 1430.13)	2.4.5.5 Consider tasks, conditions, and standards from the Functional Area Analysis (CJCSM /3170.01C) 2.4.6 Educational analysis. A process of reviewing the educational requirements, developing educational goals, and developing statements for achieving the goals. 2.4.7 Occupational analysis. A process of identifying tasks that are closely related and grouped under an occupational specialty. 2.4.8 Mission analysis. A process of reviewing mission requirements, and developing a mission statement, mission segments, collective task statements, and arranging the segments and tasks in a hierarchical relationship. 2.4.9 Job analysis. Identifies the jobs that define an occupational skill area and identifies duties and tasks that comprise each job							
2.5	Legacy Operator/Maintainer Vignettes	2.5.1 Complements 2.3, specialized HFE interview and validation process that translates operator/ maintainer interpretations of mission activities into process sequence descriptions that systems engineers can use as a basis for system specification and design							
2.6	Generate Design Reference Missions	2.6.1, Enabled by 2.5, Mission descriptions that in combination tap the full range of functional capabilities of the system							

2.7	Perform Function Allocation analysis	2.7.1 Much more informed version of work begun in 1.6, allocating tasks to humans and machines in a way that adds value to capability in term of cost, safety and performance. Exploits relative strengths of man vs. machine!!							
2.8	Human Reliability Assessment (HRA)	2.8.1 Based on predictions about compontent technologies, systematic prediction of errors that could be made by the humans in the system							
2.9	Update of Hazard Analysis, Threat/Hazard Assessment (THA): Preliminary Hazard Analysis (PHA) and Requirements Hazard Analysis (RHA)	2.9.1 Systematic prediction of conditions inherent in normal operations (including combat) that might lead to death, disability, illness, injury, or performance deterioration. 2.9.2 Derive initial SOH requirements/ 2.9.3 Update hazaards lists							
2.10'	Initial Manpower Estimate Analysis; Generate TDRA (Top Down Requirements Analysis)	2.10.1 Based on analyses to date, updated modeling and analysis against operational needs to generate manpower estimate working with A1 tools, representatives and process stakeholders (LCOM, etc.) 2.10.2 Conduct initial TDRA [Compute time-on-task for readiness conditions and mission scenarios 2.10.3 Produce data to support manpower determination from the allocated functions and tasks / Initial Workload Analysis 2.10.4 Perform an analysis of alternatives for manpower optimization [Identify capability gaps in manpower reduction. Quantify workload reductions for each specific alternative (AoA)] 2.10.5 Derive initial Manpower requirements /Identify constraints and limitations							

2.11	Ergonomics/biomechanical / anthropometric assessment	2.11.1 Preliminary analysis of notional human touch point (HTP) taking into account form, fit and function to accommodate both static and dynamic human at work; includes accessability and egress during emergency situations and normal work							
2.12	Initial Human Machine Interface (HMI) assessment	2.12.1 Preliminary analysis of interface design considerations primarily related to controls and displays but extending to any human touch point, with or without the use of tools and the design and diversity of the tools themselves							
2.13	Review LCMP draft	2.13.1 Identify stakeholders and update assumptions for current program state							
2.14	Review TEMP draft	2.14.1 Identify stakeholders and update assumptions for current program state							
2.15	Activate risk management process	2.15.1 Establish detailed administrative processes for project HSI issues log (in HSIP)							
2.16	Syncronize with DoDAF and or incorporate/roll-up into SEMP	2.16.1 Coordinate with RM on current state of OV-4 and CONOPS; begin specification of HV-B, D-1, and F-1. Review information and data components required to begin populating all HVs							

2.17	Consider high ROI use of mock-ups for physical layouts of HTPs	2.17.1 Formally consider / plan generating mock-ups to allow high-level assessment of safety, communications, workflow, usability, and general form and fit of design alternatives. These are especially useful when experienced legacy system operators and maintainers are involved in these assessments							
2.18	Incorporate requirement for contractor generated HSIP(s) and associated source selection criteria in Request for Proposals (RFPs)	2.18.1 Review RFP language, CDRLs and DIDs for HSI Planning activities for each Human Performmance							
2.19	Apply analysis findings to Test and Evaluation Strategy (TES) and TEMP	2.19.1 Special analysis to update thresholds, objectives, and evolving criteria for DT&E and eventually OT&E							
2.20'	Conduct formal development of human-centered source selection criteria for RFPs at Milestone (MS) A	2.20.1 HSI review of Source Selection Criteria for developmental RFPs							

HRL	Activity	Sub-Activity Detail	Acquisition &Sustainment Toolkit Linkages	Integration Notes and Comments	Target Documents (e.g. ICD or RFP)	Action OPR (generally within HSI WG)	References	Products (of Activity)	Rough Cost Estimate
HRL3= Component Human Touch Point Resolution: Refining Requirements Thresholds	**HRL-3 activities should occur as soon as possible after MS A , prior to MS B. Nominally about mid-way to**								
3.1	HSI Assessment ~ HRL3 (HSIA-3).With formal conversion from portfolio/project to Program at MSA, PM must assess completion of HRL 1 &2 activities with emphasis on continuity and partnership with MAJCOM RM HSI WG/IPT MSA Phase analytic activities to date	3.1.1 Manpower /Workload/ Functional Allocation 3.1.2 Personnel / KSA clusters / selection/ retention/ career path 3.1.3 Training /KSAs 3.1.4 Environment 3.1.5 Survivability / Situation Awareness/ Kll Chain Analysis/ Force Protection/ Egress systems 3.1.6 Habitabiltiy / Sustained Ops/ Facilities 3.1.7 Occupational Health 3.1.8 Safety/ HFACs 3.1.9 Human Factors Engineering 3.1.9.1 Refine user needs, characteristics, and environmental constraints 3.1.9.2 Support prototyping and capability based technology down-selection 3.1.10 HSI WG review HSI issues log and mitigaton progress 3.1.11 HSI WG specifies and recommends risk matrix outcomes and HRL assignment to PM							
3.2	Update/revise HSIP	3.2.1 Using worksheet as described in HRL-1 to update sequence of activities remaining							

3.3	Analysis to support manpower estimates	3.3.1 Emphasis on updating manning estimates as component HTPs are resolved 3.3.2 Update ME data where appropriate							
3.4	Second iteration of TSRA	3.4.1 Update ISD analyses 3.4.2 Explore training technology options in components (embedded training?; distributed training?)							
3.5	Update HSI issues log	3.5.1 Emphasis on HFE design resolutions of issues							
3.6	Initial estimates of MPT costs	3.6.1 Increasing detail in cost estimation process 3.6.1.1 Participate in HSI IPT: Perform analyses to support development of the ME 3.6.1.2 Refine and finalize ME							
3.7	Syncronize with DoDAF and or incorporate/roll-up into SEMP	3.7.1 Provide updated information to RM for continued expansion of OVs 5, 6, & 7, and CONOPS; 3.7.2 Continue specification of HV-C-1 and begin populating all HVs as component data evolves. 3.7.3 Update design reference mission scenarios as needed.							
3.8	Ensure HSIA updated for any newly introduced component technologies	3.8.1 Update HSIA for any introduced component technology. (Especially important for commercial off the shelf (COTS))							

3.9	Initiate Cognitive Task Analysis Process to inform component technology developments	3.9.1 Begin component Cognitive Task Analyses (feeds over to 3.7.2 and 3.7.3)							
3.10.	Update THA and HRA	3.10.1 Update either HRA or THA or both 3.10.2 Udate HFACs or similar nanacodes as components gel							
3.11	Initiate Ergonomics / biomechanical / anthropometric assessment processes	3.11.1 Analysis of evolving HTPs taking into account form, fit and function to accommodate both static and dynamic human at work; includes accessability and egress during emergency situations and normal work							
3.12	Plan modeling to inform human-in-the-loop analyses and assessments based on cost benefit	3.12.1 Conduct analysis and negotiate specification of Independent Variables (IVs) for linear modeling. Select IVs in part based on factors that can be manipulated in man-in-the-loop ((MITL) usually simulation-based) experiments. Modeling then can reduce complex, multivariable solution space followed by iterative MITL validation in medium- to high-fidelity simulation							
3.13	Update Human Machine Interface (HMI) assessment	3.13.1 Analysis of interface design considerations primarily related to controls and displays but extending to any human touch point, with or without the use of tools and the design and diversity of the tools themselves							
3.14	Consider high ROI use of mock-ups for physical layouts of HTPs	3.14.1 Evaluate use of mock-ups to allow high-level assessment of safety, communications, workflow, usability, and general form and fit of design alternatives. These are especially useful when experienced legacy system operators and maintainers are involved in these assessments							

3.15	Subsystem Hazard Analysis (SSHA)	3.15.1 Emerging Subsystem Hazard Analysis (SSHA)							
3.16	Apply analysis findings to TEMP	3.16.1 Special analysis to update thresholds, objectives, and evolving criteria for DT&E and OT&E							
HRL	**Activity**	**Sub-Activity Detail**	**Acquisition &Sustainment Toolkit Linkages**	**Integration Notes and Comments**	**Target Documents (e.g. ICD or RFP)**	**Action OPR (generally within HSI WG)**	**References**	**Products (of Activity)**	**Rough Cost Estimate**
HRL4= Component Human Touch Point Engineering Parameters and Human Performance	**HRL-4 activities should occur as soon as possible after MS A and prior to MS B. Nominally prior to SRR.**								
4.1	HSI Assessment ~ HRL4 (HSIA-4)	4.1.1 Assessment based on best available solution description across all HSI domains to define level of risk in each. Each domain dictates critical items of consideration bearing on system design depending on the (initially likely, and later definite) HTPs in a system as it evolves. Risk, for purposes of HRLs, is mitigated by professional analytical and managerial activities that link critical items of consideration to domain-specific design decisions, including well-informed trade-offs. 4.1.2 HSI WG review HSI issues log and mitigaton progress 4.1.3 HSI WG specifies and recommends risk matrix outcomes and HRL assignment to RM/PM							

4.2	Update/revise HSIP	4.2.1 Using worksheet as described in HRL-1 to update sequence of activities remaining							
4.3	Update/revise LCMP	4.3.1 Update current LCMP							
4.4	Update Human Machine Interface (HMI) assessment	4.4.1 Analysis of interface design considerations primarily related to controls and displays but must be extended to any human touch point, with or without the use of tools and the design and diversity of the tools themselves. 4.4.2 Perform technology assessments (with representative users) and evaluate HFE based technology/system requirements, user characteristics, and human performance 4.4.3 Cognitive walkthroughs/HMI/HCI Evaluations/ Human Performance Evaluations and Risk Analyses 4.4.4 Conduct trade studies to assess trade-offs between technologies. 4.4.5 Conduct trade studies to assess trade-offs between technologies. 4.4.6 Identify HFE technical risks and mitigation strategies included specification of applicable guides and standards 4.4.7 Provide technology down selection recommendations 4.4.8 Review sequencing and execution of component usability testing							

4.5	Consider high ROI use of mock-ups for physical layouts of HTPs	4.5.1 Formally consider mock-ups to allow high-level assessment of safety, communications, workflow, usability, and general form and fit of design alternatives. These are especially useful when experienced legacy system operators and maintainers are involved in these assessments							
4.6	Analysis of support availability for training needs and manpower / personnel requirements	4.6.1 Communicate with RM and HSI functionals to take initial opportunity to bring critical stakeholders from using and supporting commands into the loop for planning long-term training and manpower support needs. Also, provides critical opportunity for early id and resolution of evolving training system gaps. 4.6.2 Participate in technology assessments to evaluate adequacy of manpower estimates and operational impacts of proposed manning solutions. 4.6.3 Refine/update workload for specific technology ops and support activities 4.6.4 Develop manpower reduction strategy 4.6.5 Assess manpower tradeoffs among technologies 4.6.6 Participate in technology assessments to evaluate personnel requirements and the adequacy of personnel-related content in the TSP 4.6.7 Assess personnel trade-offs between technologies							
4.7	Subsystem Hazard Analysis (SSHA)	4.7.1 Conduct/update Subsystem Hazard Analysis (SSHA)							

4.8	Iterative Tranining system evolution	4.8.1 Participate in technology assessments to evaluate adequacy of the TSP and operational impacts of proposed training solutions. 4.8.2 Identify and document formal training courses and training resource requirements 4.8.3 Type of training curricula 4.8.4 Ensure sufficient funding to support training needs,training devices,equipment 4.8.5 Assess training trade-offs between technologies							
4.9	Apply analysis findings to TEMP	4.9.1 Conduct special analysis to update thresholds, objectives, and evolving criteria for DT&E and OT&E							
4.10.	Begin formal development of human-centered source selection criteria for RFPs at MS B	4.10.1 Based on requirements being translated into RFPs, begin drafting HSI-specific source selection criteria							
4.11	Syncronize with DoDAF and or incorporate/roll-up into SEMP	4.11.1 Provide updated information to RM for continued expansion of OVs 5, 6, & 7, and CONOPS; 4.11.2 Continue specification of HV-C-1 and continue populating all HVs as component data evolves. 4.11.3 Update design reference mission scenarios as needed							

HRL	Activity	Sub-Activity Detail	Acquisition &Sustainment Toolkit Linkages	Integration Notes and Comments	Target Documents (e.g. ICD or RFP)	Action OPR (generally within HSI WG)	References	Products (of Activity)	Rough Cost Estimate
HRL5=Limited System Human Performance Parameters/ Demonstration	**HRL-5 activities should occur as soon as possible after MS A and prior to MS B. Nominally prior to SFR.**								
5.1	HSI Assessment ~ HRL5 (HSIA-5)	5.1.1 Assessment based on best available Solution Description across all HSI domains to define level of risk in each. Each domain dictates critical items of consideration bearing on system design depending on the (initially likely, and later definite) HTPs in a system as it evolves. Risk, for purposes of HRLs, is mitigated by professional analytical and managerial activities that link critical items of consideration to domain-specific design decisions, including well-informed trade-offs. 5.1.2 HSI WG review HSI Issues log and mitigaton progress 5.1.3 HSI WG specifies and recommends risk matrix outcomes and HRL assignment to RM/PM							
5.2	Update/revise HSIP	5.2.1 Using worksheet as described in HRL-1 to update sequence of activities remaining							

5.3		5.3.1 Refine/update Personnel requirements / KPP and KSA in CDDs 5.3.2 Assist in final technology selections/Ensure Personnel needs can be met appropriately/addresses Personnel requirements							
5.4	Confirm SOH findings incorporated in design and fed forward to sustainment planning	5.4.1 Confirm that safety and Occupational Health design features have been incorporated 5.4.2 Non-materiel safety and health hazard mitigations have been incorporated into PESHE							
5.5	Subsystem Hazard Analysis (SSHA)	5.5.1 Review component technologies and update Hazard Analyses							
5.6	Update Human Machine/Equipment Interface (HMI) assessment	5.6.1 Refine/update HFE requirements 5.6.2 HMI/ HCI usability assessments of component Workspaces/ Communication systems/ Human Performance & Safety/Occ Health features/ 5.6.3 Refine KPPs and KSAs in CDD 5.6.4 Assist in final technology selections, assure solution: 5.6.4.1 Addresses HFE requirements 5.6.4.2 Addresses user needs and goals 5.6.4.3 Satisfies concept and mission objectives 5.6.4.4 Incorporates HFE design standards 5.6.5 Component performance testing. Update predictive models based on outcomes							

5.7	Update ME	5.7.1 Refine/update Manpower requirements 5.7.2 Assure final technology selections addresses Manpower requirements 5.7.3 Ensure MEs can be met appropriately							
5.8	Apply analysis findings to TEMP	5.8.1 Special analysis to update thresholds, objectives, and evolving criteria for DT&E and OT&E							
5.9	Translate design decisions into design specifications and/or life cycle sustainment factors	5.9.1 Continue formal development of human-centered source selection criteria for RFPs at MS B 5.9.2 Update/revise LCMP							
5.10.	Syncronize with DoDAF and or incorporate/roll-up into SEMP	5.10.1 Syncronize with DoDAF and or incorporate/roll-up into SEMP							
5.11	Update Training for design decisions and update sustainment accordingly	5.11.1 Update Training for design decisions and update sustainment accordingly							
5.12	Synchronize with DoDAF	5.12.1 Ensure that human reliability issues have been identified for action in design or appropriate process within the HV 5.12.2 Provide updated information to RM for continued expansion of OVs 5, 6, & 7, and CONOPS; continue specification of HV-C-1 & D-2, and 5.12.3 Continue populating all HVs as component data evolves. 5.12.4 Update design reference mission scenarios as needed							

HRL	Activity	Sub-Activity Detail	Acquisition &Sustainment Toolkit Linkages	Integration Notes and Comments	Target Documents (e.g. ICD or RFP)	Action OPR (generally within HSI WG)	References	Products (of Activity)	Rough Cost Estimate
HRL6=Field (Relevant Environment) Validation of Human Performance Prototypes	**HRL-6 activities should occur prior to MS B.**								
6.1	HSI Assessment ~ HRL6 (HSIA-6)	6.1.1 Assessment based on best available Solution Description across all HSI domains to define level of risk in each. Each domain dictates critical items of consideration bearing on system design depending on the (initially likely, and later definite) HTPs in a system as it evolves. Risk, for purposes of HRLs, is mitigated by Professional analytical and managerial activities that link critical items of consideration to domain-specific design decisions, including well-informed trade-offs. 6.1.2 HSI WG review HSI Issues log and mitigaton progress 6.1.3 HSI WG specifies and recommends risk matrix outcomes and HRL assignment to RM/PM							
6.2	Update/revise HSIP	6.2.1 Using worksheet as described in HRL-1 to update sequence of activities remaining							

6.3	Update/revise LCMP	6.3.1 Update/revise LCMP							
6.4	Subsystem Hazard Analysis (SSHA)	6.4.1 Subsystem Hazard Analysis (SSHA)							
6.5	System Hazard Analysis (SHA)	6.5.1 Perform system safety analyses 6.5.2 Derive and finalize safety requirements and Criteria for Analysis, 6.5.2.1 develop preliminary hazard list 6.5.2.2 Initiate preliminary hazard analysis and threat hazard assessment 6.5.3 Complete initial /PESHE							
6.6	Iterative usability testing	6.6.1 Conduct Evalulations of Human Perfomance embedded in demontration system; 6.6.2 Update predictive models based on outcomes							
6.7a	Apply analysis findings to TEMP	6.7.1 Special analysis to update thresholds, objectives, and evolving criteria for DT&E and OT&E 6.7.2 Participate /in the T&E /IPT 6.7.3 Perform analyses to ensure appropriate HFE considerations are included in system technology development// Operational /Workflow Analysis/ Task Analyses 6.7.4 Assist in development of the system functional baseline and Functional Allocation Analyses 6.7.5 Develop the HFE T&E//V&V program plans//Methods/Metrics /Analyses /Tools 6.7.6 Review and provide inputs to preliminary designs allocated baseline							

6.7b	Apply analysis findings to TEMP	6.7.7 Provide recommendations based on Manpower analyses 6.7.8 Assess gaps between personnel capabilities and system needs 6.7.9 Provide Personnel inputs to functional allocation 6.7.10 Provide recommendations based on Personnel analyses 6.7.11 Assess gaps between personnel capabilities and system needs 6.7.12 Provide Personnel inputs to functional allocation 6.7.13 Provide recommendations based on Training analyses							
6.8	Complete formal development of human-centered source selection criteria for RFPs at MS B	6.8.1 Complete formal development of human-centered source selection criteria for RFPs at MS B							
6.9	Syncronize with DoDAF	6.9.1 Provide updated information to RM for continued expansion of OVs 2, 3, & 5, and CONOPS; continue specification of HV-E-1, 2, &3, HV-C-2, and HV-G. 6.9.2 Continue populating all HVs as component data evolves. 6.9.3 Update design reference mission scenarios as needed							
6.10.	Collect evidence for validation and verification (V&V), and acceptance against HSI requirements, including interoperability.	6.10.1 Collect evidence for validation and verification (V&V), and acceptance against HSI requirements, including interoperability							

HRL	Activity	Sub-Activity Detail	Acquisition &Sustainment Toolkit Linkages	Integration Notes and Comments	Target Documents (e.g. ICD or RFP)	Action OPR (generally within HSI WG)	References	Products (of Activity)	Rough Cost Estimate
HRL7=Final DT&E Human Performance Parameters	**HRL-7 activities should occur as soon as possible after MS B. Nominally by CDRA.**								
7.1	HSI Assessment ~ HRL7 (HSIA-7)	7.1.1 Assessment based on best available Solution Description across all HSI domains to define level of risk in each. Each domain dictates critical items of consideration bearing on system design depending on the (initially likely, and later definite) HTPs in a system as it evolves. Risk, for purposes of HRLs, is mitigated by Professional analytical and managerial activities that link critical items of consideration to domain-specific design decisions, including well-informed trade-offs. Emphasis at this stage should be optimizing transfer of HSI issues and consideration information to the sustainment community, most specifically logistics center managers. 7.1.2 HSI WG review HSI Issues log and mitigaton progress 7.1.3 HSI WG specifies and recommends risk matrix outcomes and HRL assignment to PM							
7.2	Update/revise HSIP	7.2.1 Using worksheet as described in HRL-1 to update sequence of activities remaining							

7.3	Update/revise LCMP	7.3.1 Assess detailed system designs to ensure they meet Manpower requirements 7.3.2 Participate in detailed system design demonstrations 7.3.3 Provide recommendations for redesign/modification and/or develop mitigation strategies for Manpower estimates as required 7.3.4 Identify potential personnel gaps based on detailed system designs 7.3.5 Update personnel requirements 7.3.6 Participate in detailed system design demonstrations							
7.4	Review and update Training systems plans	7.4.1 Identify potential gaps in training based on detailed system designs 7.4.2 Update training requirements 7.4.3 Update KSAs 7.4.4 Update media analysis of training tasks 7.4.5 Review selections to determine if still appropriate based on current system design/ 7.4.6 Participate in detailed system design demonstrations 7.4.7 Design training solutions (ILT / ICW/ Embedded training (ACAT 1)/Performance aids 7.4.8 Develop JQR/PQS Sheet 7.4.9 Develop and prototype training solutions 7.4.10 Develop an assessment plan for training solutions							
7.5	System Hazard Analysis (SHA)	7.5.1 Assess detailed system design to ensure they meet SOH requirements 7.5.2 Provide recommendations for redesign modification and/or develop mitigation strategies for SOH as required 7.5.3 Participate in detailed system design demonstrations 7.5.4 Provide recommendations for redesign/modification and/or develop mitigation strategies for Personnel qualifications as required 7.5.5 Refine/update system safety analyses 7.5.6 Finalize hazard analyses							

7.6	Iterative usability testing	7.6.1 Evalulations of Human Perfomance embedded in prototype system; 7.6.2 Support development of detailed design specifications for HMI/workstations/workspaces/ HCI/ Facilities 7.6.3 Iteratively develop and review prototypes, mockups, screenshots, drawings and simulations// Plan and conduct cognitive walkthroughs/ usability testing/ heuristic evaluations/ workspace evaluations 7.6.4 Evaluate initial system designs and specifications having an impact on human performance and safety 7.6.5 Verify detailed system designs 7.6.6 Address HFE requirements 7.6.7 Incorporate HFE design standards 7.6.8 Support concept/mission goals/objectives/ satisfy user needs and goals 7.6.9 Mitigate known human performance risks 7.6.10 Provide recommendations to resolve detailed system design deficiencies impacting users and system performance 7.6.11 Update predictive models based on outcomes							
7.7	Apply analysis findings to TEMP	7.7.1 Special analysis to update thresholds, objectives, and evolving criteria for DT&E and OT&E 7.7.2 Develop a user-centered test plan to evaluate initial detailed system designs 7.7.2.1 Include operational use cases and operationally relevant tasks 7.7.3 Finalize HFE requirements 7.7.4 Determine assessment methods 7.7.5 Identify metrics 7.7.6 Develop a user-centered test plan to evaluate the system during component and integration testing 7.7.7 Identify scope of test demonstra- tions and develop procedures, materials, and instruments 7.7.8 Identify high risk areas for testing operationally relevant use cases and tasks 7.7.9 Operationally define human performance metrics/ validation approaches for HFE requirements							

7.8	Syncronize with DoDAF	7.8.1 Provide updated information to RM for continued expansion of SVs 1, 2, 3, 6, 7, 8, 9, and CONOPS; 7.8.2 Continue specification of HV-F-2 & 3, and HV-G. 7.8.3 Continue populating all other HVs as system evolves							
7.9	Error and fault analysis	7.9.1 Analysis to cover human error peromance, equipment operability, safety procedures and error recovery mechanisms. 7.9.2 Conduct trials to support V&V, and acceptance against HSI requirements, including interoperability							
7.10.	Begin formal development of human-centered source selection criteria for RFPs at MS C	7.10 Begin formal development of human-centered source selection criteria for RFPs at MS C							
7.11	Review and update HSI issues log	7.11.1 Review and update HSI issues log							
HRL	**Activity**	**Sub-Activity Detail**	**Acquisition &Sustainment Toolkit Linkages**	**Integration Notes and Comments**	**Target Documents (e.g. ICD or RFP)**	**Action OPR (generally within HSI WG)**	**References**	**Products (of Activity)**	**Rough Cost Estimate**
HRL8=OT&E Human Performance Parameters	**HRL-8 activities should occur roughly at MS C, in support of LRIP**								

8.1	HSI Assessment ~ HRL8 (HSIA-8)	8.1.1 Assessment based on best available Solution Description across all HSI domains to define level of risk in each. Each domain dictates critical items of consideration bearing on system design depending on the (initially likely, and later definite) HTPs in a system as it evolves. Risk, for purposes of HRLs, is mitigated by Professional analytical and managerial activities that link critical items of consideration to domain-specific design decisions, including well-informed trade-offs. Emphasis at this stage should be optimizing transfer of HSI issues and consideration information to the sustainment community, most specifically logistics center managers. 8.1.2 HSI WG review HSI issues log and mitigaton progress 8.1.3 HSI WG specifies and recommends risk matrix outcomes and HRL assignment to PM							
8.2	Update/revise HSIP	8.2.1 Using worksheet as described in HRL-1 to update sequence of activities remaining							
8.3a	Update/revise HFE for Design and LCMP	8.3.1 Evaluate system components having an impact on human performance and safety 8.3.1.1 Identify human performance risks 8.3.1.2 Provide HFE mitigation strategies 8.3.2 Provide inputs to developmental test plans to ensure they include appropriate human performance assessments for integrated system testing to address: 8.3.2.1 HFE requirements 8.3.2.1.1 User interaction with HW/SW interfaces, 8.3.2.1.2 COTS integration, and 8.3.2.1.3 operational workflows 8.3.2.2 HFE high risk areas 8.3.2.3 Multiple user roles 8.3.3 Collect human performance data during system test events 8.3.3.1 HFE Requirements Compliance Assessments 8.3.3.2 HFE System Performance Assessments 8.3.3.3 Usability Testing							

8.3b	Update/revise HFE for Design and LCMP	8.3.4 Document HFE-related system performance issues (i.e., PTRs) 8.3.5 Verify system compliance with HFE requirements 8.3.6 Analyze results from HFE testing 8.3.6.1 Report significance of findings based on user impact and system performance risk 8.3.6.2 Incorporate impact assessment/ risk analysis design recommendations/ Human Performance Mitigation Strategies 8.3.7 Support the review and development of job aids 8.3.8 Participate in ECP development 8.3.8.1 Generate HFE related ECPs 8.3.8.2 Review ECPs for human performance impacts 8.3.9 Participate in /system test events							
8.4	Update/revise Manpower/Personnel inputs for Design and LCMP	8.4.1 Perform analysis and reporting on Manpower related test events, data collected, and findings 8.4.2 Revise the ME to reflect system design 8.4.2.1 Provide recommendations based on findings to support manning as needed 8.4.3 Perform analysis and reporting on Personnel related test events, data collected, and findings							
8.5	Review and update Training systems for Design and LCMP	8.5.1 Assess training solutions during initial system component demonstrations 8.5.2 Refine training solutions based on findings from initial system component demonstrations/ Trainer installations/ Equipment, facility, and TTE plan 8.5.3 Modify ILE 8.5.4 Provide inputs to developmental test plans to ensure they include appropriate assessments of training solutions for integrated system testing 8.5.5 Participate in system test events 8.5.6 Arrange for pilot/cadre course to train users 8.5.6.1 Assess results from training pilot course 8.5.6.2 Compare to learning objectives 8.5.7 Revise training solutions based on findings from integrated system demonstrations and pilot course 8.5.8 Deliver final training solution for use in production and deployment phase							

8.6	System Hazard Analysis (SHA)//Operating and Support Hazard Analysis (O&SHA)	8.6.1 Participate in system test events 8.6.2 Perform analyses and reporting on SOH related test events, data collected, and findings 8.6.3 Revise the System Safety Analyses and Hazard analyses to reflect demonstrated system design 8.6.4 Provide recommendations based on findings to support system design changes							
8.7	Iterative usability testing	8.7.1 Evalulations of Human Perfomancce embedded in integrated system; 8.7.2 Update predictive models based on outcomes							
8.8	Apply analysis findings to TEMP	8.8.1 Special analysis to update thresholds, objectives, and evolving criteria for OT&E							
8.9	Complete formal development of human-centered source selection criteria for RFPs at MS C	8.9.1 Update draft HP-related source selection criteria, primarily from integrated prototype DT&E and advanced usability testing							
8.10.	Syncronize with DoDAF	8.10.1 Provide updated information to RM for continued expansion of SVs 1, 2, 3, 6, 7, 8, 9, and CONOPS; 8.10.2 Continue specification of HV-F-2 & 3, and HV-G. 8.10.3 Continue populating all other HVs as system evolves							
8.11.	Review and update HSI issues log	8.11.1 Review and update HSI issues log							

HRL	Activity	Sub-Activity Detail	Acquisition &Sustainment Toolkit Linkages	Integration Notes and Comments	Target Documents (e.g. ICD or RFP)	Action OPR (generally within HSI WG)	References	Products (of Activity)	Rough Cost Estimate
HRL9= Sustainment: Initiation of Capability Gap Feedback Cycle	**HRL 9 Hand-off transition from Acquisition PM to Logistics/sustainment PM as keeper of HSI Plan/documentation. Shred copy to next block Acq PM.**			Emphasis at this stage should be optimizing transfer of HSI issues and consideration information to the sustainment community, most specifically logistics center managers.					
9.1	**HSI Assessment ~ HRL9 (HSIA-9)**	**9.1.1 Assessment based on best available Solution Description across all HSI domains to define level of risk in each. Each domain dictates critical items of consideration bearing on system design depending on the (initially likely, and later definite) HTPs in a system as it evolves. Risk, for purposes of HRLs, is mitigated by Professional analytical and managerial activities that link critical items of consideration to domain-specific design decisions, including well-informed trade-offs.** **9.1.2 HSI WG review HSI Issues log and mitigaton progress** **9.1.3 HSI WG specifies and recommends risk matrix outcomes and HRL assignment to PM** **9.1.4 Define process and responsibilities for drafting *Program Increment HSI Transition Final Report* for Logistics/ Sustainment PM**		Transition to Logistics/Sustainment Program Management is Emphasis and Keystone to HSI success					

9.2	HFE IO T&E support	9.2 Review verify and develop HFE installation criteria/ 9.2.1.1 Provide recommendations for improvement 9.2.1.2 Consider human performance, workload, and safety/ Identify gaps or potential installation problems 9.2.1.3 Perform analysis of LRIP deficiencies to Identify human performance risks 9.2.1.4 Provide HFE mitigation strategies 9.2.2 Develop a user-centered assessment plan to support OT&E considering performance quality/ compatibility/ interoperability/ system capabilities/ 9.2.3 Participate in IOT&E 9.2.3.1 Validate HFE-based system changes 9.2.3.2 Collect user feedback and human performance data 9.2.3.3 Report significance of findings based on user impact and system performance risk 9.2.4 Review HSI ISSUE reports and discuss HSI migations/tradeoffs 9.2.5 Verify and validate final HFE-related production items							
9.3	HFE FO T&E support	9.3.1 Collect and analyze user feedback and service use data from the post-deployed system 9.3.2 Analyze known system performance issues/program trouble reports 9.3.3 Identify HFE lessons learned and life cycle improvements 9.3.4 Provide ECP recommendations 9.3.5 Provide mitigation strategies for outstanding HFE issues and risks 9.3.6 Develop a user-centered assessment plan to support FOT&E considering performance/ quality/ compatibility/ interoperability/ system capabilities 9.3.7 Participate in FOT&E 9.3.7.1 Analyze results from FOT&E to assess and redesign aspects of the system/ workstations/ workspaces/ allocation of functions/ procedures/ job aids/ Human-Machine Interfaces/ Human-Computer Interfaces 9.3.8 Develop an operations and support plan to monitor and assess the system and collect feedback from users							

9.4a	HFE FOC support and Logistics/Sustainment Transition	9.4.1 Identify/document HFE lessons learned and lifecycle improvements from fielded system and feed forward 9.4.2 Collect feedback from operational users across multiple platforms and commands 9.4.3 Perform a system assessment to identify capability gaps 9.4.4 Document system areas that have been significantly impacted by HFE including: performance risk mitigation safety & health, quality of life, affordability 9.4.4.1 Analyze and model post-product improvements for the next incremental build of Human-Machine Interfaces, facilities, workstations/workspaces/ Human-Computer Interfaces							
9.4b	HFE FOC support and Logistics/Sustainment Transition	9.4.4.2 Provide HFE based recommendations for system modernization and increment upgrades 9.4.4.3 Identify and assess design/engineering tradeoffs for modernization 9.4.4.3.1 Identify advanced technologies that will have a significant positive impact on human performance 9.4.5 Review /HSI ISSUE /reports and /discuss HSI /tradeoffs from an HFE design impacts perspective 9.4.6 Participate to include HFE summary in *Program Increment HSI Transition Final Report* for Logistics/ Sustainment PM							
9.5	Training FOC support and Logistics/Sustainment Transition	9.5.1 Transition Post-Fielding Training Evaluation Analysis (PFTEA). Validation of system training in operational setting and formal certification for FOC 9.5.2 Conduct a training effectiveness evaluation// identify training deficiencies and root causes 9.5.3 Provide recommendations to correct training deficiencies / incorporate representative mission scenarios 9.5.4 Assess human performance and effectiveness of training transfer 9.9.5 Redesign training procedures and decision aids 9.5.6 Identify/document training lessons learned and feed forward 9.5.7 Incorporate findings into *Program Increment HSI Transition Final Report* for Logistics/Sustainment PM		The PFTEA is required to validate institutional training to ensure training requirements are met.					

9.6	**Manpower/Personnel FOC support and Logistics/Sustainment Transition**	**9.6.1 Verify ME survey** **9.6.2 Verify system installations meet Manpower requirements** **9.6.3 Assess effects of equipment installations on workload** **9.6.4 Identify/document manpower lessons learned and feed forward** **9.6.5 Identify and document areas where Manpower has had a significant impact** **9.6.6 Provide modernization /recom-mendations that would optimize manpower** **9.6.7 Collect feedback from users to identify/document personnel lessons learned and feed forward** **9.6.8 Review HSI issue reports and discuss HSI tradeoffs** **9.6.9 Incorporate findings into *Program Increment HSI Transition Final Report* for Logistics/Sustainment PM**							
9.7	**SOH FOC support and Logistics/Sustainment TransitionOperating and Support Hazard Analysis (O&SHA)**	**9.7.1 Verify system installations meet SOH requirements** **9.7.2 Finalize the SOH footprint and attributes. Identify/document safety and occupational health lessons learned and feed forward** **9.7.3 Complete a System (fielded) Safety Analysis; include /sustaining hazard analysis for the fielded system and Incorporate findings into *Program Increment HSI Transition Final Report* for Logistics/Sustainment PM**							
9.8	**Syncronize with DoDAF**	**9.8.1 Provide updated information to RM for continued expansion of SVs 1, 2, 3, 6, 7, 8, 9, and CONOPS;** **9.8.2 Continue specification of HV-F-2 & 3, and HV-G.** **9.8.3 Continue populating all other HVs as system evolves.** **9.8.4 Archive as part of *Program Increment HSI Final Report* for Logistics/Sustainment PM**		SVs: system interface description, communication, matrix, information exchange matrix, evolution description, technology forcast, and performance parameter matrix. Training requirements (HV-F-2), training resources (HV-F-3), and metrics (HV-G).					

APPENDIX G. HRL SUBJECT MATTER EXPERT EVALUATION QUESTIONNAIRE

ABOUT THIS REVIEW

You are invited to participate in a Subject Matter Expert (SME) review of the evolving concept of the Human Readiness Level (HRL). As this is the first iteration of the HRL framework, your valuable input and feedback will be used to refine and ultimately advance its ongoing definition and validation.

Please note that all data collected in this review will be kept strictly confidential. Your participation in the review and your responses to the review items will not be disclosed. Additionally, no Personal Identifying Information (PII) will be collected in this review.

HRL BACKGROUND & FRAMEWORK STRUCTURE

In order to effectively translate capability needs and technology opportunities into stable, affordable, and well-managed acquisition programs, proper measurement and management of technology maturity must occur. The Technology Readiness Level (TRL) has proven to be the tool and process of choice for assessing the maturity of developing technologies. Yet, due mainly to its intended focus, the TRL has proven inappropriate to consistently capturing the human-related attributes of technology and their association with technology readiness. It is in response to this recognized issue that the Human Readiness Level (HRL) framework was created.

The intended purposes of HRLs are to:
1. directly support the S&T community and Resource and Program Managers by providing a risk management structure and process that is similar to the TRL structure and process, but that explicitly links technology development to the effective design and specification of human-centered systems in Defense Acquisition;
2. directly support the Requirements and Program Managers by providing a potentially exhaustive list of candidate activities to be tailored for each program to populate HSI Planning with data collection and analytical activities needed to inform requirements, acquisition, and sustainment documents of record; and,
3. support the policy-driven mandate to implement HSI by identifying the most critical HSI-specific data collection/analysis activities as factors and elements in cost estimation during the Analysis of Alternatives process; this will "fund the requirement" by directly informing PPBS insertion to complement traditional Work Breakdown Structure-based program factors and elements.

To accomplish these ends, the HRL framework must provide a time/milestone-sensitive roadmap of activities (explicitly linked to existing Acquisition and Sustainment Toolkits, for example, and related guidance and standards) that: a) detail critical organizational

milestones that ensure functional commitment to Human Systems Integration (HSI); and b) define HSI domain-sensitive data collection and analysis activities. **The primary measure of HSI risk and maturity level is based on the execution of those milestone-sensitive management and analytical activities.**

At the core of the HRL concept is the activities list, the central topic for this review. In a later stage of HRL development, an explicit process will be defined for risk management and reporting. The process will define how to assign each HRL as an assessed program achievement value, a risk management metric. The metric will depend upon the determination of a scale value from 1 (*HSI baselining & commitment*) to 9 (*capability gap feedback cycle*). A program determined to be at HRL-1 would have achieved the lowest level of HSI readiness, where the initial activation of HSI commitment and processes occurs. By the time the program has reached HRL-9, it will have progressed through significant HSI analyses, requirement threshold refinements, field validations of human performance prototypes, and extensive developmental and operational Test and Evaluation (T&E) of human performance parameters. As with TRLs, what constitutes an acceptable and appropriate Human Readiness Level (and so, level of programmatic risk) will depend upon a large number of program-specific details, most critically linked to where a program of record is in its life cycle.

By structuring appropriate sequencing of HSI activities and tracking the progress of HSI planning and execution, the HRL distinguishes itself as a significant risk management tool for process owners and decision makers in Defense Acquisition. **The following is the first evaluation of the HRL framework's worth and usability.** Based on your feedback, our plan is to develop an updated draft of the candidate list and framework to form the basis for a series of developmental workshops to "fill in the matrix" and develop this into as practical a tool as is possible. Your inputs will be critical to this effort.

INSTRUCTIONS

The first worksheet (labeled: ***HRL Framework Draft1***) in the attached *Excel* Spreadsheet contains the content for your review. **Columns A, B & C contain HSI candidate activities, while columns D through J contain proposed column headings for future HRL framework efforts. Only for the first three columns in the intended framework have the cells been filled in completely.**

The following items are designed to gain feedback as to the *accuracy*, *ease of use*, and *completeness* of the HRL framework activities lists. The items are organized into five separate groups. The first four grouping of statements reflect the HRL's recommended milestone progression in the Defense Acquisition Life Cycle. For instance, HRL-2 is the criterion threshold to be met at Milestone A, therefore the first set of items pertains to HRLs 1 and 2. The last set of items found in the fifth group involves the proposed categories for future HRL framework efforts.

Using the attached draft of the HRL Framework, for each item below, circle or underline the response that best describes your feelings. Please add comments as needed.

HRLs 1/2

*HRL-2 should be achieved prior to ***Milestone A*** approval.

HRL Descriptions – Column A

1. The HRL descriptions are clearly understood.

Strongly Agree Agree Neutral Disagree Strongly Disagree

Comments

2. The HRL descriptions reflect appropriate timing within the acquisition life cycle.

Strongly Agree Agree Neutral Disagree Strongly Disagree

Comments

3. No critical information is missing from the HRL descriptions.

Strongly Agree Agree Neutral Disagree Strongly Disagree

Comments

Activity – Column B

4. The activities and their descriptions are clearly understood.

Strongly Agree Agree Neutral Disagree Strongly Disagree

Comments

5. The activities are appropriately timed within the acquisition life cycle.

Strongly Agree Agree Neutral Disagree Strongly Disagree

Comments

6. No critical information is missing from the activities and their descriptions. Strongly Agree Agree Neutral Disagree Strongly Disagree Comments
Sub-Activity Details – Column C
7. The HRL sub-activity descriptions are clearly understood. Strongly Agree Agree Neutral Disagree Strongly Disagree Comments
8. The HRL sub-activity details reflect appropriate timing within the acquisition life cycle. Strongly Agree Agree Neutral Disagree Strongly Disagree Comments
9. No critical items of activity are missing from the sub-activities list. Strongly Agree Agree Neutral Disagree Strongly Disagree Comments
<u>HRLs 3/4/5/6</u> *HRL – 6 should be achieved prior to ***Milestone B*** approval.
HRL Descriptions – Column A
10. The HRL descriptions are clearly understood. Strongly Agree Agree Neutral Disagree Strongly Disagree Comments
11. The HRL descriptions reflect appropriate timing within the acquisition life cycle. Strongly Agree Agree Neutral Disagree Strongly Disagree Comments

12. No critical information is missing from the HRL descriptions. Strongly Agree Agree Neutral Disagree Strongly Disagree Comments
Activity: Column B
13. The activities and their descriptions are clearly understood. Strongly Agree Agree Neutral Disagree Strongly Disagree Comments
14. The activities are appropriately timed within the acquisition life cycle. Strongly Agree Agree Neutral Disagree Strongly Disagree Comments
15. No critical information is missing from the activities and their descriptions. Strongly Agree Agree Neutral Disagree Strongly Disagree Comments
Sub-Activity Details: Column C
16. The HRL sub-activity descriptions are clearly understood. Strongly Agree Agree Neutral Disagree Strongly Disagree Comments
17. The HRL sub-activity details reflect appropriate timing within the acquisition life cycle. Strongly Agree Agree Neutral Disagree Strongly Disagree Comments

18. No critical items of activity are missing from the sub-activities list.

Strongly Agree Agree Neutral Disagree Strongly Disagree

Comments

HRLs 7/8

*HRL – 8 should be achieved prior to ***Milestone C*** approval.

HRL Descriptions: Column A

19. The HRL descriptions are clearly understood.

Strongly Agree Agree Neutral Disagree Strongly Disagree

Comments

20. The HRL descriptions reflect appropriate timing within the acquisition life cycle.

Strongly Agree Agree Neutral Disagree Strongly Disagree

Comments

21. No critical information is missing from the HRL descriptions.

Strongly Agree Agree Neutral Disagree Strongly Disagree

Comments

Activity: Column B

22. The activities and their descriptions are clearly understood.

Strongly Agree Agree Neutral Disagree Strongly Disagree

Comments

23. The activities are appropriately timed within the acquisition life cycle.

Strongly Agree Agree Neutral Disagree Strongly Disagree

Comments

24. No critical information is missing from the activities and their descriptions. Strongly Agree Agree Neutral Disagree Strongly Disagree Comments
Sub-Activity Details: Column C
25. The HRL sub-activity descriptions are clearly understood. Strongly Agree Agree Neutral Disagree Strongly Disagree Comments
26. The HRL sub-activity details reflect appropriate timing within the acquisition life cycle. Strongly Agree Agree Neutral Disagree Strongly Disagree Comments
27. No critical items of activity are missing from the sub-activities list. Strongly Agree Agree Neutral Disagree Strongly Disagree Comments
HRL 9 *HRL – 9 represents the highest HRL to be achieved and signifies the initiation of the capability gap feedback cycle.
HRL Descriptions: Column A
28. The HRL descriptions are clearly understood. Strongly Agree Agree Neutral Disagree Strongly Disagree Comments
29. The HRL descriptions reflect appropriate timing within the acquisition life cycle. Strongly Agree Agree Neutral Disagree Strongly Disagree Comments

30. No critical information is missing from the HRL descriptions. Strongly Agree Agree Neutral Disagree Strongly Disagree Comments
Activity: Column B
31. The activities and their descriptions are clearly understood. Strongly Agree Agree Neutral Disagree Strongly Disagree Comments
32. The activities are appropriately timed within the acquisition life cycle. Strongly Agree Agree Neutral Disagree Strongly Disagree Comments
33. No critical information is missing from the activities and their descriptions. Strongly Agree Agree Neutral Disagree Strongly Disagree Comments
Sub-Activity Details: Column C
34. The HRL sub-activity descriptions are clearly understood. Strongly Agree Agree Neutral Disagree Strongly Disagree Comments
35. The HRL sub-activity details reflect appropriate timing within the acquisition life cycle. Strongly Agree Agree Neutral Disagree Strongly Disagree Comments

36. No critical items of activity are missing from the sub-activities list.

Strongly Agree Agree Neutral Disagree Strongly Disagree

Comments

Proposed Categories (Columns) for Future HRL Framework Efforts

A & S Toolkit: Column D

37. **This column heading and information in the column cells will be very relevant in the HRL framework matrix for all 9 HRL activity listings.**

Strongly Agree Agree Neutral Disagree Strongly Disagree

Comments

38. **This column heading and information in the column cells will be very useful in the HRL framework matrix for all 9 HRL activity listings.**

Strongly Agree Agree Neutral Disagree Strongly Disagree

Comments

Integration Notes and Comments: Column E

39. **This column heading and information in the column cells will be very relevant in the HRL framework matrix for all 9 HRL activity listings.**

Strongly Agree Agree Neutral Disagree Strongly Disagree

Comments

40. **This column heading and information in the column cells will be very useful in the HRL framework matrix for all 9 HRL activity listings.**

Strongly Agree Agree Neutral Disagree Strongly Disagree

Comments

Target Documents: Column F
41. **This column heading and information in the column cells will be very relevant in the HRL framework matrix for all 9 HRL activity listings.** Strongly Agree Agree Neutral Disagree Strongly Disagree Comments
42. **This column heading and information in the column cells will be very useful in the HRL framework matrix for all 9 HRL activity listings.** Strongly Agree Agree Neutral Disagree Strongly Disagree Comments
Action OPR: Column G
43. **This column heading and information in the column cells will be very relevant in the HRL framework matrix for all 9 HRL activity listings.** Strongly Agree Agree Neutral Disagree Strongly Disagree Comments
44. **This column heading and information in the column cells will be very useful in the HRL framework matrix for all 9 HRL activity listings.** Strongly Agree Agree Neutral Disagree Strongly Disagree Comments
References: Column H
45. **This column heading and information in the column cells will be very relevant in the HRL framework matrix for all 9 HRL activity listings.** Strongly Agree Agree Neutral Disagree Strongly Disagree Comments

46. **This column heading and information in the column cells will be very useful in the HRL framework matrix for all 9 HRL activity listings.** Strongly Agree Agree Neutral Disagree Strongly Disagree Comments
Products of Activity: Column I
47. **This column heading and information in the column cells will be very relevant in the HRL framework matrix for all 9 HRL activity listings.** Strongly Agree Agree Neutral Disagree Strongly Disagree Comments
48. **This column heading and information in the column cells will be very useful in the HRL framework matrix for all 9 HRL activity listings.** Strongly Agree Agree Neutral Disagree Strongly Disagree Comments
Rough Cost Estimate (person days and $): Column J
49. **This column heading and information in the column cells will be very relevant in the HRL framework matrix for all 9 HRL activity listings.** Strongly Agree Agree Neutral Disagree Strongly Disagree Comments
50. **This column heading and information in the column cells will be very useful in the HRL framework matrix for all 9 HRL activity listings.** Strongly Agree Agree Neutral Disagree Strongly Disagree Comments

51. **You would recommend no additional column topics to populate the matrix.**

Strongly Agree Agree Neutral Disagree Strongly Disagree

Comments; please list any additions you would recommend and your rationale, if appropriate

#51 is the last rating item summarizing your review. Please add any comments, issues, or concerns below. Thank you for your time and effort in support of this work in progress.

APPENDIX H. HRL SUBJECT MATTER EXPERT CASE STUDY QUESTIONNAIRE

ABOUT THIS REVIEW

You are invited as key HSI practitioners in a program office to participate in a review of activity lists and matrix headings contained in the first installment of the evolving concept of the Human Readiness Level (HRL). As this is the first iteration of the HRL framework, your valuable input and feedback will be used to refine and ultimately advance its ongoing definition and validation.

Please note that all data collected in this review will be kept strictly confidential. Your participation in the review and your responses to the review items will not be disclosed. Additionally, no Personal Identifying Information (PII) will be collected in this review.

HRL BACKGROUND & FRAMEWORK STRUCTURE

In order to effectively translate capability needs and technology opportunities into stable, affordable, and well-managed acquisition programs, proper measurement and management of technology maturity must occur. The Technology Readiness Level (TRL) has proven to be the tool and process of choice for assessing the maturity of developing technologies. Yet, due mainly to its intended focus, the TRL has proven inappropriate to consistently capturing the human-related attributes of technology and their association with technology readiness. It is in response to this recognized issue that the Human Readiness Level (HRL) framework was created.

The intended purposes of HRLs are to:
1. directly support the S&T community and Resource and Program Managers by providing a risk management structure and process that is similar to the TRL structure and process, but that explicitly links technology development to the effective design and specification of human-centered systems in Defense Acquisition;
2. directly support Requirements and Program Managers by providing a potentially exhaustive list of candidate HSI-specific data collection and analytical activities to be tailored for each program to populate HSI Planning to inform requirements, acquisition, and sustainment documents of record; and,
3. support the policy-driven mandate to implement HSI by identifying the most critical HSI-specific data collection/analysis activities as factors and elements in cost estimation during the Analysis of Alternatives process; this will “fund the requirement” by directly informing Planning, Programming, and Budgeting System (PPBS) insertion to complement traditional Work Breakdown Structure-based program factors and elements.
To accomplish these ends, the HRL framework must provide a time/milestone-sensitive roadmap of activities (explicitly linked to existing System Engineering processes, Acquisition and Sustainment Toolkits, for example, and related guidance and standards)

that: a) detail critical organizational milestones that ensure functional commitment to Human Systems Integration (HSI); and b) define HSI domain-sensitive data collection and analysis activities and a clear process for their management. The primary measure of HSI risk and maturity level will be based on the execution of those milestone-sensitive management and analytical activities.

At the core of the HRL concept is the activities list, the central topic for this review. In a later stage of HRL development, an explicit process will be defined for risk management and reporting. The process will define how to assign each HRL as an assessed program achievement value, a risk management metric. The metric will depend upon the determination of a scale value from 1 (*HSI baselining & commitment*) to 9 (*capability gap feedback cycle*). A program determined to be at HRL-1 would have achieved the lowest level of HSI readiness, where the initial activation of HSI commitment and processes occurs. By the time the program has reached HRL-9, it will have progressed through significant HSI analyses, requirement threshold refinements, field validations of human performance prototypes, and extensive developmental and operational Test and Evaluation (T&E) of human performance parameters. As with TRLs, what constitutes an acceptable and appropriate Human Readiness Level (and so, level of programmatic risk) will depend upon a large number of program-specific details, most critically linked to where a program of record is in its life cycle.

The key to a successful HSI acquisition strategy is having an accurate HSI Plan (HSIP) in place. The following is the first evaluation of the HRL framework's ability to directly support the creation and execution of an HSIP. Based on your feedback, our plan is to develop an updated draft of the activity candidate list and framework to form the basis for a series of developmental workshops to "fill in the matrix" and develop this into as practical a tool as is possible. Your inputs will be critical to this effort.

INSTRUCTIONS

The first worksheet (labeled: ***HRL Framework Draft1***) in the attached *Excel* Spreadsheet contains the content for your review. Columns A, B & C contain HSI **candidate activities, while columns D through J contain proposed column headings for future HRL framework efforts. Only for the first three columns in the intended framework have the cells been filled in completely.**

The following items are designed to gain feedback as to the *ease of use*, and *completeness* of the HRL framework when used to support the creation and execution of an HSIP. For each item below, circle or underline the response that best describes your feelings. Please add comments as needed.

1. The milestone-sensitive HSI activities listed and the HRL matrix (once completed) will provide an effective framework for an HSI working group to tailor for comprehensive HSI planning. Strongly Agree Agree Neutral Disagree Strongly Disagree Comments
2. The HRL framework contains all of the appropriate HSI activities that would be necessary to manage, create, and sustain an HSIP throughout a program's life cycle. Strongly Agree Agree Neutral Disagree Strongly Disagree Comments
3. Using the HRL framework as an HSI maturity metric can benefit HSI risk identification and management within the HSIP. Strongly Agree Agree Neutral Disagree Strongly Disagree Comments
4. The HRL framework facilitates easier HSI issue-tracking and HSI execution accountability. Strongly Agree Agree Neutral Disagree Strongly Disagree Comments

5. The column headings in the spreadsheet (after columns A, B & C being reviewed above) represent a <u>complete</u> list of the key areas of information needed to perform effective HSI Planning. Strongly Agree Agree Neutral Disagree Strongly Disagree Comments (please recommend any additional headings you think are needed)
6. The column headings in the spreadsheet (after columns A, B & C being reviewed above) represent <u>the most relevant</u> list of the key areas of information needed to perform effective HSI Planning. Strongly Agree Agree Neutral Disagree Strongly Disagree Comments (please identify headings you think might be eliminated as redundant or irrelevant)
7. The following section is designed to gain feedback as to the relative value/importance of the current (columns A, B & C) and proposed categories (columns D – J) contained in the HRL framework when being used to support an HSIP. Please assign a rank to each of the ten categories listed below in order of value/importance to HSI Planning. ("1" is most valuable/important; tied values in the ranking are acceptable; please comment where appropriate; and, especially, specify any additional columns you believe need to be added or any current heading(s) that you feel should be eliminated)
a. HRL –
b. Activity –
c. Sub Activity Detail –
d. Acquisition & Sustainment (A & S) Toolkit Linkages –
e. Integration Notes & Comments –

f. Target Documents –
g. Action OPR –
h. References –
i. Products (of Activity) –
j. Rough Cost Estimate –

7. j. is the last rating item summarizing your review. Please add any additional comments, issues, or concerns below. Thank you for your time and effort in support of this work in progress.

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APPENDIX I. HRL SUBJECT MATTER EXPERT EVALUATION COMMENTS

<u>HRLs 1/2</u> *HRL-2 should be achieved prior to ***Milestone A*** approval.
HRL Descriptions – Column A
1. The HRL descriptions are clearly understood. *"Could be better, but not bad"* *"The description for HRL 1 is rather clear and straight forward. However for HRL 2, reference to "component technology development" is not real clear. Since HRL 2 is in support of MS A and subsequent Technology Development Phase, suggest something like "HSI analysis suite in support of AoA" or "HSI analysis suite in support of MS A" or "HSI analysis suite in support of proceeding to Technology Development Phase."* *"1 is relatively clear, but the only issue is this can be done at any phase based on when HSI involvement is initiated. I understand that the intent is to begin involvement pre MS A, but even if you don't this activity can be accomplished at any point HSI gets involved. 2 is somewhat less clear to me, I'm not sure what the suite is referring to, is it a toolkit or checklist? It may become more clear as I read through the information."*
2. The HRL descriptions reflect appropriate timing within the acquisition life cycle. *"Getting a commitment and actually getting engaged will be very hard prior to having an established program. Granted – ideally this should be engaged with DP and CCTD, etc. How much you can actually accomplish before MS B will be challenging. Being informed by CBA and CBP and other analyses may provide help."* *"Timing within acquisition cycle cannot be ascertained from Column A descriptions."* *"Strongly agreed, it is very important to begin as early as possible in the process. Only question is what happens when you're starting after MS A? Do you still go through these or should they have already been done? It may become OBE in the future, but I'm thinking about programs that are currently in process."*

3. No critical information is missing from the HRL descriptions. *“Appears to be comprehensive. Need more time to review.”* *“The description for HRL 2 does not relay ultimate performance objective. As read, the objective for HRL 2 is to keep HSI practitioners employed. Besides shortfalls mentioned above, descriptors should describe the ultimate outcome or goal for the HRL.”* *“I would like to understand what the suite is in HRL 2. I know you’re planning on doing this in the future, but identify where each HRL is tied to TRLs and MRLs to better support the technology being developed, since HRLs are more process focused and TRLs/MRLs are product focused.”*
Activity – Column B
4. The activities and their descriptions are clearly understood. *“References to “design” and “system” are out of place this early in the acquisition process where you’re considering concept alternatives (materiel and non-materiel). Some of the activities have same title (ex 11.a and 11.b). Recommend activity state what it is that is to be performed. Begin each activity with “Perform”, “Conduct”, “Generate”, “List”, etc.”* *“1 – Most of them are easily understood but I’m not sure how well they will be understood by non-HSI individuals. 1.2 and think you may want to differentiate 1.11a and b and 1.12a and b more the detail shouldn’t be different if it’s the same activity at the same stage.”* *“Activity listing format will make it hard for future development of cost elements. Can have a descriptor column for detail.”*
5. The activities are appropriately timed within the acquisition life cycle. *“Timing for phase adequate.”* *“References to “design” and “system” are out of place this early in the acquisition process where you’re considering concept alternatives (materiel and non-materiel).”* *“Some of the documents are not required at MS A. But I agree that the other efforts should begin at this stage to ensure effective HSI.”* *“These timings are probably program-dependent, but they seem reasonably aligned with the DODI 5000.02 timeline, but I am unclear as to what processes are supporting CJCSI 3170 activities that proceed the acquisition program. Current information indicates that HSI SMEs need to be operating in support of potential programs to bring forward lessons learned and early risk mitigation issues well before Milestone A.”*

6. No critical information is missing from the activities and their descriptions. *"Needs further scrutiny."* *"We don't know what we don't know. We may find that there are critical drivers that are not under our purview or within our awareness on any given program, or FoS/SoS. This framework will probably best be constructed as an iterative model that accommodates periodic modifications (additions / deletions)."*
Sub-Activity Details – Column C
7. The HRL sub-activity descriptions are clearly understood. *"Under 2.4.5 – don't understand inclusion of reference to 2.4.1 training situation analysis (TSA). Either numbering is wrong or information has been inserted in the wrong place."* *"I like how they're broken into steps. Makes them easier to follow and accomplish each activity."*
8. The HRL sub-activity details reflect appropriate timing within the acquisition life cycle. *"As mentioned above with the Activity detail. Some of the documents/efforts may not be in the appropriate place but I think it will take trying it out on a program to really see what can be accomplished pre MS A. At this level I can't think of specifics besides some of the documents, but there may be some modeling that can't be done as fully as anticipated per the descriptions."* *"Probably realistically a little early on many of them. May start before A, but unlikely to have the necessary funding, fidelity and support necessary to take all the tasks to completion or any real depth."* *"1.6.4 Difficult to estimate cost until manpower is more thoroughly explored as in 1.8.6. What is the difference between 1.8.4 and 1.11.2?"* *"I think as we examine the data that will populate columns d, f, & g timing will become clearer. There are activities that may be premature other than a outline for future phases and other activities that must be done very early in the JCIDS process or completed as continuous underlying HSI S&T activities that are pulled off the shelf into the JCIDS process in order to effectively impact (timely input, already accepted HSI requirements) a specific material solution. The cycle time is too short to undertake some HSI analyses/activities and drive requirements & functional allocation decisions."*

9. No critical items of activity are missing from the sub-activities list.

"Needs further scrutiny -- appears to be comprehensive."

"Unable to determine. The answer will become more apparent over time in application of the HRL process."

HRLs 3/4/5/6

*HRL – 6 should be achieved prior to ***Milestone B*** approval.

HRL Descriptions – Column A

10. The HRL descriptions are clearly understood.

"Reference to "component" in HRLs 3&4 can mislead that system level was bypassed or circumvented. Not clear what is "touch point resolution" in HRLs 3 & 4."

"I'm not sure that the prototypes are going to be completely operational by MS B. I know the intent is to follow along with the TRLs but HRL 6 with the current definition may be somewhat optimistic."

11. The HRL descriptions reflect appropriate timing within the acquisition life cycle.

"Timing within acquisition cycle cannot be ascertained from Column A descriptions."

12. No critical information is missing from the HRL descriptions.

"Needs more scrutiny."

"Descriptors should better distinguish maturity levels, particularly HRLs 3 & 4."

"This should be discussed in more detail at the workshop. But for now I think top level is well defined."

Activity: Column B

13. The activities and their descriptions are clearly understood.

"Could provide some more explanation / description."

"It is difficult to assess sufficiency of activity descriptions when it is unclear when the milestone points are unclear."

14. The activities are appropriately timed within the acquisition life cycle. *"…don't assume program start at MS A -- normally not formalized till much later."* *"Stating HRLs 3-5 all should occur "as soon as possible after MS A" does not help discriminate between the three. Timing for activity completion should be more defined. Recommend tailoring HRL-4 activities/attainment by SRR/RFP completion. Recommend tailoring HRL-5 activities/attainment by source selection/SFR completion. Recommend tailoring HRL-6 activities/attainment by PDR completion (before or after MS B)."*
15. No critical information is missing from the activities and their descriptions. *"Needs more scrutiny."*
Sub-Activity Details: Column C
16. The HRL sub-activity descriptions are clearly understood. *"HTPs not well understood / articulated throughout."* *"Further detail needs to be provided for some domains. I.E. Safety / Occupational Health Activities. Yes they looked at but actual activity is not the domain."*
17. The HRL sub-activity details reflect appropriate timing within the acquisition life cycle.
18. No critical items of activity are missing from the sub-activities list. *"Add 3.6.1.3 Inform cost estimate from manpower estimate."*
<u>HRLs 7/8</u> *HRL – 8 should be achieved prior to ***Milestone C*** approval.
HRL Descriptions: Column A
19. The HRL descriptions are clearly understood.
20. The HRL descriptions reflect appropriate timing within the acquisition life cycle.
21. No critical information is missing from the HRL descriptions. *"Need to incorporate HSI trade-offs and integration of the domains."*

Activity: Column B
22. The activities and their descriptions are clearly understood.
23. The activities are appropriately timed within the acquisition life cycle. *"The timing for HRL-7 activities seems appropriate. Difficult to ascertain timing for "update/revise HFE for design and LCMP" references. Reference to source selection by LRIP is out of place. Generally, PM may exercise option on the existing contract for contractor to produce LRIP units."*
24. No critical information is missing from the activities and their descriptions. *"The analysis by CDR for HRL-7 needs to be pretty comprehensive as the design is pretty much locked in after this point and changes become difficult to influence/implement. Appears activities for HRL-8 should be better tailored toward what resulted from DT&E, and how will deficiencies be addressed prior to OT&E."* *"You may want to add additional information about DT&E and OT&E participation and the DRs associated with these tests. Also, include inputs/final analysis and trade-offs important to design reviews. Some of these may be based on financial implications but that needs to be identified. Final opportunity to influence design."*
Sub-Activity Details: Column C
25. The HRL sub-activity descriptions are clearly understood. *"Generally understand descriptions, but some should be improved. Activities related to "participate" are rather unclear."*
26. The HRL sub-activity details reflect appropriate timing within the acquisition life cycle. *"The timing for activities generally seem appropriate. References to providing input to development test plans (8.3.2) and source selection criteria (8.9.1) are too late in process."*
27. No critical items of activity are missing from the sub-activities list. *"Need to find a way to take findings from DT&E and inform / support OT&E test readiness evaluation / report. Almost all HRL testing can be accomplished unobtrusively in DT&E and in enough detail to know what to expect in OT&E. HRL determination in OT&E will have to be a natural outcome from the actual tests – it must be unobtrusive. Also may want to get involved in OAs and EOAs to refine HRL 6 info in preparation for final DT&E parameters."*

HRL 9 *HRL – 9 represents the highest HRL to be achieved and signifies the initiation of the capability gap feedback cycle.
HRL Descriptions: Column A
28. The HRL descriptions are clearly understood. *“Recommend this HRL/description be aligned with Post Implementation Review.”*
29. The HRL descriptions reflect appropriate timing within the acquisition life cycle.
30. No critical information is missing from the HRL descriptions.
Activity: Column B
31. The activities and their descriptions are clearly understood.
32. The activities are appropriately timed within the acquisition life cycle.
33. No critical information is missing from the activities and their descriptions.
Sub-Activity Details: Column C
34. The HRL sub-activity descriptions are clearly understood.
35. The HRL sub-activity details reflect appropriate timing within the acquisition life cycle.
36. No critical items of activity are missing from the sub-activities list. *“It is important to include feedback throughout the entire acq process, not just during HRL 9.”*

Proposed Categories (Columns) for Future HRL Framework Efforts
Acquisition & Sustainment Toolkit Linkages: Column D
37. **This column heading and information in the column cells will be very relevant in the HRL framework matrix for all 9 HRL activity listings.** *"It will likely be critical for more than HRL 9 only. Since Logistics considerations should, like manpower and training issues, be dealt with early, it is not unlikely that much lower HRL levels could be influenced by the ASTK."*
38. **This column heading and information in the column cells will be very useful in the HRL framework matrix for all 9 HRL activity listings.**
Integration Notes and Comments: Column E
39. **This column heading and information in the column cells will be very relevant in the HRL framework matrix for all 9 HRL activity listings.** *"Agreed, additional details will be especially useful for individuals tasked with HSI that are not very familiar with it or with the acquisition process."*
40. **This column heading and information in the column cells will be very useful in the HRL framework matrix for all 9 HRL activity listings.**
Target Documents: Column F
41. **This column heading and information in the column cells will be very relevant in the HRL framework matrix for all 9 HRL activity listings.** *"Agreed, individuals can go look at those documents for additional detail on program."* *"Recommend considering list of target documents for <u>NEXT</u> phase here as well to highlight upcoming tasks for planning purposes."*
42. **This column heading and information in the column cells will be very useful in the HRL framework matrix for all 9 HRL activity listings.**

Action OPR: Column G
43. **This column heading and information in the column cells will be very relevant in the HRL framework matrix for all 9 HRL activity listings.** *"There should be a program office OPR, a Sponsor/MAJCOM OPR, and an HSI OPR."*
44. **This column heading and information in the column cells will be very useful in the HRL framework matrix for all 9 HRL activity listings.** *"Especially when individuals move on, it is nice to have a POC to go back to or identify that the work has been in process."*
References: Column H
45. **This column heading and information in the column cells will be very relevant in the HRL framework matrix for all 9 HRL activity listings.**
46. **This column heading and information in the column cells will be very useful in the HRL framework matrix for all 9 HRL activity listings.** *"Will provide information to individuals performing the tasks on exactly what they need to do and where to go to find information."* *"Consider hyper linking or a separate reference database/dictionary."*
Products of Activity: Column I
47. **This column heading and information in the column cells will be very relevant in the HRL framework matrix for all 9 HRL activity listings.** *"Strongly agree… for building off of effort in next HRL or activity"*
48. **This column heading and information in the column cells will be very useful in the HRL framework matrix for all 9 HRL activity listings.**

Rough Cost Estimate: Column J
49. **This column heading and information in the column cells will be very relevant in the HRL framework matrix for all 9 HRL activity listings.** *"Provides PM with information on the cost of doing the HSI at each level/activity for a program."* *"Agree with the spirit of what this is attempting to accomplish. I suspect that a cost estimate is not necessary for every single sub-activity. There are a lot of government activities that are taken out of hide, like commenting on a CDD or HP writing a HSIP. Eventually, you probably should highlight the ones you especially need the input for cost estimations. Since this spreadsheet lists activities to be completed by government HSI WG, then the cost estimate apparently will capture costs associated government management cost portion of the pie."* *"Since all the activities have such variability depending on the program, advocacy of PM, etc. I'm wondering what validity the estimate will have."*
50. **This column heading and information in the column cells will be very useful in the HRL framework matrix for all 9 HRL activity listings.** *"Will allow PM to pick and choose the most important activities based on budget restrictions."* *"If cost is an ultimate part of goal. Possible listing in effort or man-hours versus person days would be relevant. Depending of labor mix, cost does not usually occur per day (i.e., contract personnel). Also might be good Ideas to include cost drivers or cost estimation relationship columns for future sourcing and appropriations."*
51. **You would recommend no additional column topics to populate the matrix.** *"Relevant to Cost, more information such as system, and drivers may be important. ROI Benefit Analysis and Trade-off columns may also be useful. Common language as used in acquisition or reports should be used for search relationships and connections (I.e. target document is good)."*

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